En-Route Constrained Airspace Concept Definition

Final Report

NASA Contract: RTO-07: NAS2-98005

September 1999

Authors

William Thedford, Ph. D.

Robert A. Vivona, M.S.

Craig Hodgdon

Prepared for: NASA Ames Research Center

Moffett Field, CA 94035-1000

System Resources Corporation

A Titan Company

TITAN

Acknowledgement

The authors wish to acknowledge the sponsor of this effort, Steve Green of NASA Ames Research Center, and to thank him for his contribution, guidance and support in the conduct of this work. Also, the authors would like to thank Dimensions International, Inc., Alexandria, VA for their permission to reprint elements of their airspace figures, as used to represent the notional displays for the Constrained Airspace Tool.

The technical support provided by the field and industry contacts listed in Appendix B were uniformly supportive and their contributions are appreciated. Mr. Gene Weilhelm, MITRE Corporation, was very cooperative in providing a description of the current status of the Collaborative Routing Coordination Tool (CRCT). Mr. Lin Lindsey, NorthWest Research Associates, was very helpful in developing an understanding of weather technology. Dr. Banavar Sridhar, NASA ARC, and Mr. Parimal CTR Kopardekar, SRC, provided current information on dynamic density.

The authors also wish to acknowledge and thank Dr. Paul Abramson, Charles Philips, and Kristine Mooso from SRC for their technical and editorial contributions to this effort.

Executive Summary

NASA's Advance Air Transportation Technologies (AATT) Program is investigating potential ground-based decision support tool (DST) development for en route controllers and managers. NASA's previous work in en route DST development has focused on Transition airspace, where aircraft trajectories are impacted by constraints associated with the transition of aircraft from en route to terminal airspace. This investigates the problems associated with aircraft in non-transitional en route airspace, termed Constrained Airspace.

A literature search was performed to identify existing work performed to identify constrained airspace problems. The results of this search were investigated with industry representatives (pilots, controllers, technology developers, etc.) to validate that these were indeed the significant problems in constrained airspace. Three general problem areas were identified. The first problem area involves negative impacts caused by a loss of airspace. The most common causes (not in order of occurrence) for lost airspace are activation of Special Use Airspace (SUA), weather cell formation, and overloaded sectors. The second problem area is the lack of identifying and taking advantage of gained airspace. Gained airspace is usually the result of SUA deactivation, weather dissipation, and sector loading reductions. The third problem area is unforeseen negative impacts caused by the acceptance of user routing requests. This is usually caused by a route change into an area of congestion that negated the users intended benefit.

Based upon the problems identified, an operational concept was developed for a DST to help Traffic Managers in the Air Route Traffic Control Centers (ARTCC) handle these problems efficiently. This DST, termed the Constrained Airspace Tool or CAT, is based upon the current Center TRACON Automation System (CTAS) architecture for trajectory generation and route probing/planning and is similar in concept to the Airspace Tool concept developed at NASA. The goal of CAT capability is to strategically identify the constrained airspace problems and to provide route planning functions to support the Traffic Management Units (TMU) in resolving the identified impacts. The capability lends itself well to TMU and Airline Operations Center (AOC) collaboration.

To support the development of the CAT operational concept, a literature search was performed to identify supporting technology and research and development efforts already under way that fulfill CAT functional requirements. System Resources Corporation leveraged its work done for AATT in evaluating FAA, NASA, MITRE, Eurocontrol and other development efforts with respect to the FAA's NAS 2005 Operational Concept requirements to identify existing efforts related to the Constrained Airspace problems. CAT functional requirements not covered by these external efforts and other required development assessments (e.g., benefits studies) are presented as proposed research areas for AATT.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

Symbols and Abbreviations

4D	Four Dimensional
AATT	Advanced Air Transportation Technologies
ADCON	Arrival Departure Control
AFSS	Automated Flight Service Station
AGFS	Aviation Gridded Forecast System
AIM	Aeronautical Information Manual
AIRMET	Airman’s Meteorological Information
AIV	Aviation Impact Variables
AOC	Airline Operations Center
ARTCC	Air Route Traffic Control Center
AT	Airspace Tool
ATC	Air Traffic Control
ATCSCC	Air Traffic Control System Command Center
AVN	Aviation model
AWC	Aviation Weather Center
AWIN	Aviation Weather Information
AWW	Severe Weather Forecasts Alerts
CAT	Constrained Airspace Tool
CDM	Collaborative Decision Making
CFR	Code of Federal Regulations
CRCT	Collaborative Routing Coordination Tool

CTAS	Center TRACON Automation System
CWA	Center Weather Advisories
CWSU	Center Weather Service Unit
DFW	Dallas Fort Worth International Airport
DMS	Demand Modulation Schedule
DMT	Demand Modulation Time
DOD	Department of Defense
DSS	Decision Support System
DST	Decision Support Tools
ECON	En Route Control
EDA	En Route Descent Advisor
ETMS	Enhanced Traffic Management System
FA	Area Forecast
FAA	Federal Aviation Administration
FARs	Federal Aviation Regulations
FCA	Flow Constrained Area
FFT	Free Flow Time
FIP	Flight Information Profile
FIS	Flight Information Services
FL	Flight Level
FSS	Flight Service Station
GA	General Aviation
HIWAS	Hazardous In-flight Weather Advisory Service
IFR	Instrument Flight Rules

ITWS	Integrated Terminal Weather System
LAX	Los Angeles International Airport
MAMS	Military Airspace Management System
MDCRS	Meteorological Data Collecting and Reporting System
NAS	National Airspace System
NASA	National Aeronautics and Space Administration
NAVAID	Navigational Aid
NCEP	National Center for Environmental Prediction
NEXRAD	Next Generation Radar
NIDS	National Information Dissemination Service
NOAA	National Oceanic and Atmospheric Administration
NOTAM	Notice to Airmen
NTSB	National Transportation Safety Board
NWP	Numerical Weather Processor
NWS	National Weather Service
OASIS	Operational and Supportability Implementation System
PGUI	Planview Graphical User Interface
PIREP	Pilot Report
PVD	Plan View Display
RAPCOM	Radar Approach Control
RLV	Reusable Launch Vehicles
RUC	Rapid Update Cycle
SAMS	Special Use Airspace Management System
SIGMET	Significant Meteorological Information

SOW	Statement of Work
SRC	System Resources Corporation
SUA	Special Use Airspace
TKE	Turbulent Kinetic Energy
TM	Traffic Manager
TMC	Traffic Management Center
TMU	Traffic Management Unit
TRACON	Terminal Radar Approach Control
URET	User Request Evaluation Tool
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions
WA	AIRMETS
WARP	Weather And Radar Processor
WS	SIGMETS
WST	Convective SIGMETS
WSMR	White Sands Missile Range
WW	Severe Weather Bulletin
ZAB	Albuquerque ARTCC

1. Introduction

1.1. Identification

This is the final report for Task Order 7: *En-Route Constrained Airspace Concept Definition* under NASA Ames Research Center Advanced Air Transportation Technologies (AATT) NRA contract NAS2-98005.

1.2. En Route Constrained Airspace Problem Definition

One of the primary goals of this task order was to identify “problems” within today’s en route airspace operations that are not a result of constraints imposed by air traffic controllers or managers in the transition of aircraft to and from en route airspace. The task order statement of work (SOW) generally describes this non-transitional “constrained” en route environment as one in which a flight “may be affected by a downstream impediment which is not related to the terminal destination.” What was not specifically identified in the SOW is the definition of a “problem.”

Within the context of the constrained airspace definition above, System Resources Corporation (SRC) defined a constrained airspace problem as any current day operation that limits the capacity, efficiency, flexibility, and/or safety of en route operations, including the operations of both service provider (air traffic) and user (airlines). Furthermore, since AATT is a project of NASA’s Capacity Program and not NASA’s Safety Program, any problems identified as solely safety related were not pursued.

Using this problem definition as a basis, constrained airspace problems can be further defined as the inability to select the most advantageous combination of route of flight and operational constraints for an aircraft (or airspace). Therefore, these problems include both the inability to select the most advantageous solution when confronted with a mandatory change and the inability to identify non-mandatory opportunities to gain operational benefits.

Some additional ground rules were added to define the scope of “constrained” en route airspace:

1. Focus on individual aircraft and how they affect the airspace operations as a whole. The airspace operation may be any presently used in the contiguous 48 states or anticipated in the future (e.g., free flight).

2. All aircraft of interest are under Instrument Flight Rules (IFR), on pre-determined flight plans, and are in en route airspace. The aircraft, in most instances, will be flying at or above Flight Level 180 (Class A airspace).

3. Events occur either after the aircraft entered en route airspace or after the aircraft is proposed to enter en route airspace (e.g., as in the case of satellite departures). Events

could or should affect the planned route of flight or, in a wider context, improve the operations of the airspace as a whole.

4. Airspace is constrained when traffic demand exceeds the capacity. The constraints are between the aircraft and its destination.

The problems and solutions of interest are those that are not related to transition to or from terminal airspace or terminal operation.

Another primary goal of this task order was to develop operational concepts that solve the identified problems. SRC focused on the identification of trajectory deviations and modifications to operations that would achieve benefits over today’s operations. It was the general intent to identify solutions that reduce the likelihood that a problem would arise (i.e., focus on strategic solutions) and propose decision support tool (DST) concepts that would help the stakeholders identify and implement desirable solutions.

To achieve capacity, efficiency, and flexibility gains, the proposed solutions focus on improving planning at the air traffic management and AOC level rather than at the controller and pilot level. This does not, however, mean that the flight deck and sector controllers are not an integral part of the solution. For General Aviation (GA) aircraft, AOCs are not available and any user collaboration is with the flight deck. In all situations, the flight deck is required to compliment AOC information by identifying any safety concerns to proposed trajectory modifications. On the controller side, it is expected that DST functionality is required at the sector level to support unavoidable tactical solutions and that this functionality will be based upon similar functionality at the traffic management level. Every attempt was made to propose DST solutions that are consistent with NASA’s current suite of en route tools. This is important to ensure that controllers and traffic managers have a consistent set of tools to approach their entire range of problems.

To support the operational concepts, SRC leveraged our work in performing gap analyses for NASA to identify existing research and technology that fulfill technical requirements of the developed operational concepts. NASA, FAA, MITRE, and Eurocontrol programs were all included in these analyses. SRC examined the FAA's "Air Traffic Services Concept of Operations for the National Airspace System in 2005 - Narrative" (Narrative) and the corresponding AATT “ATM/OPSCON” (Milestone 1.0.0) to confirm that the approach taken and the solutions proposed are consistent with the envisioned future from both the FAA and NASA AATT perspective (Appendix D). Elements of the operational concepts not covered by existing research or technology were identified as potential research and development areas for AATT.

Section 2 consists of descriptions of the identified problems, a proposed solution, related technology, and identified AATT research activities and opportunities. Conclusions are found in Section 3. Supporting information is located in the appendicies.

2. Results

This chapter consists of sections describing each of the three identified problems, the problem solution, related technology, and proposed AATT research activities and opportunities.

The general considerations are:

Flight Domain: The problem occurred post departure while the aircraft are in en route airspace or the event will occur after the aircraft are predicted to enter en route airspace.

Time Domain: The objective is to resolve the problems strategically versus tactically. The strategic solution is characterized by collaboration between the users and service providers as may be appropriate with the final decisions including all of the significant factors (e.g., best fuel reroute or downstream capacity limitations cause by considered options).

Stakeholders: The main influence is on those directly responsible for strategic decisions including traffic managers and AOCs.

A literature search of past work on en route airspace problems was performed and the results are in Appendix A. The results of the literature search were discussed with industry representatives including commercial pilots, air traffic controllers, air traffic management quality assurance agents of the FAA, industry and private technology developers, and fellow researchers with an interest in the en route phases of operation. The complete list of contacts that were made can be found in Appendix B. This background information was used to define the three problem areas discussed in the next section.

A fourth problem area titled "Information Dissemination" was identified through the course of our research, but was predominately a safety issue. Information regarding this problem area is in Appendix E.

2.1. Problem Definition

The three general problem areas defined in this section are lost airspace, gained airspace, and requested route changes. The objective in solving lost airspace problems is to minimize the impact of losing the airspace. When airspace is gained, on the other hand, the solution objective is to gain benefits by allowing aircraft trajectories to take advantage of the newly available airspace. In the case of the requested route change problem, the objective is to facilitate the acceptance of a user request without undue negative impact on air traffic operations (e.g., excessive density or complexity). Examples are provided of each problem and the impacts are described.

2.1.1. Problem 1: Lost Airspace

This problem is the effect of changes in the National Airspace System (NAS) that reduces the available airspace in a specific location and time. The focus is on those flights that are to be in the location during the active time.

The general objective is to mitigate the airspace capacity impact by implementing strategic solutions. These strategic decisions should be generally beneficial to service providers and individually desirable by users.

Regardless of the cause, the trajectory modifications and redistribution of traffic takes time and resources, and potentially causes flight arrival or departure delays, selection of undesirable alternative routes, and extension of flight time or distance. The root cause may be anything from a weather forecast change, to an unexpected activation of an SUA, to airspace congestion.

Factors: The four-dimensional (4-D) (Latitude, Longitude, Altitude, and Time) route of flight is through a region of lost airspace at the identified active time. The 4D route currently scheduled should be changed to avoid the unavailable airspace. The identified causes are:

1. **Weather:** A region of airspace identified as unsuitable or undesirable for flight operations due to weather (e.g., Pilot Report (PIREP) indicating turbulence or a forecast change identifying convective activity).

2. **Special Use Airspace (SUA):** SUA activation, decision for the Department of Defense to utilize an SUA not previously scheduled, or a decision to not use a specified SUA or region of airspace that is open.[1]

3. **Airspace Complexity Increase:** The increase in airspace complexity (e.g., utilizing measures of dynamic density) may necessitate trajectory (e.g., route) modifications.

Three case examples are provided.

2.1.1.1. Case 1: Weather Forecast Change Eliminated Route Options

Weather is a common cause for trajectory modification. This particular example illustrates how a restricted area and weather can combine to produce a lost airspace problem.

A standard routing for a flight from Los Angeles International Airport (LAX) to Dallas/ Fort Worth International Airport (DFW) is south of the White Sands Missile Range (WSMR) as shown in Figure 1 . There are agreements that allow routing over Mexico in

---

[1] For example a Military Operations Area (MOA) will not be used, even when open, if separation can not be maintained between military and civilian aircraft by the service provider.

the immediate border area when conditions require it. (The Letter of Agreement between Albuquerque Center and the controlling agency for White Sands Missile Range can be found in Appendix C.) There is still a narrow corridor below the southern tip of the WSMR. (More details on the WSMR are contained in Appendix G.)

Any constraint in this corridor necessitates re-routing the affected aircraft north of the range or through the center of the range on high altitude jet route J65-166. Since J65-166 is normally closed, routing to the north is the common solution. Early decision making will reduce the impact on the flight. If the decision to re-route is delayed, the deviation in the route may be considerable, as is shown by the blue line in the figure.

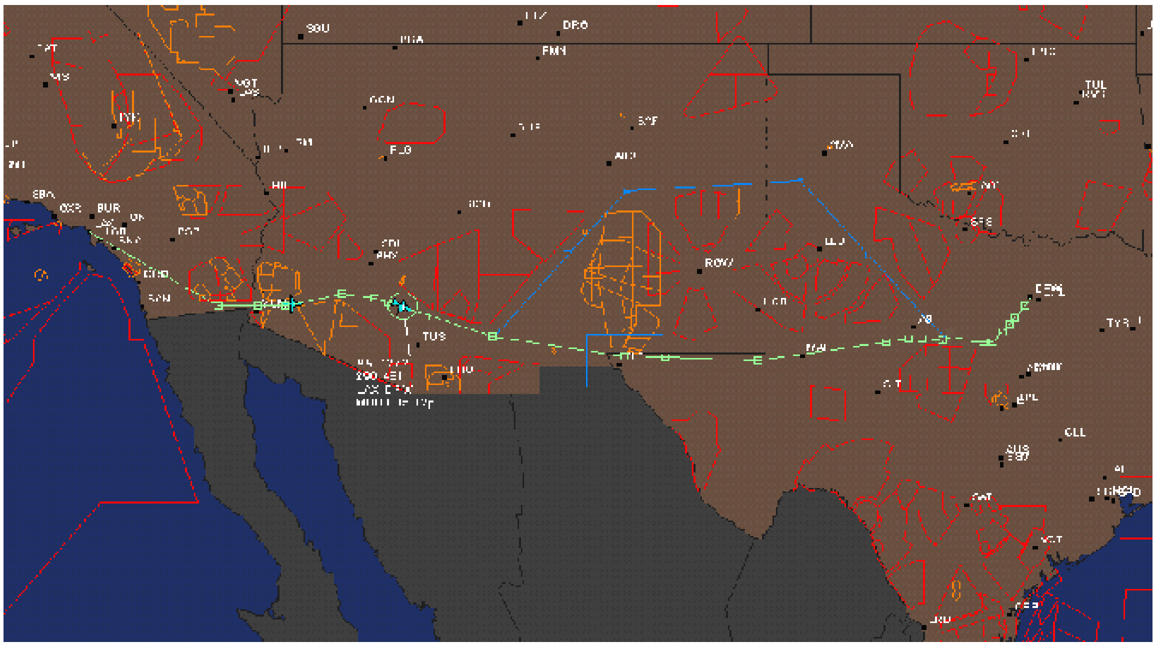


Figure 1 Weather Forecast Change Eliminated Route Options

2.1.1.2. Case 2: SUA Closure

Although the air traffic controllers interviewed indicated that SUA is a very significant concern, an initial analysis has provided results that show savings (flight time, flight distance and dollar savings) are relatively small.[2] This analysis focused primarily on the impact of SUA activation/de-activation knowledge at the pre-departure flight planning stage and modeled only Prohibited and Restricted Areas as SUA. By not including Military Operations Areas, Military Training Routes, and other elements of SUA in their definition, this analysis may not be conservative. A significant amount of airspace is

---

[2] Datta, K., Barrington, C.: "Effects of Special Use Airspace on Economic Benefits of Direct Flights," Sverdrup Corporation, 1997. Some specific results are presented in Appendix G.

excluded by the limited definition and the impacts of this airspace on operations are similarly reduced. The exclusion of these other SUA elements was most likely due to the difficulty in modeling them from an aggregate sense, since the availability of these SUA components is not always easily defined. Also, though the identification of savings during pre-departure planning is a valid component of the potential benefits to be gained by better use of SUA, it is not the only component. The effective handling of impacts due to changes in SUA availability when the aircraft are en route is expected (from controller comments) to also provide benefits. This latter area of en route impacts of SUA status changes is the focus of the SUA problems in this study.

Special Use Airspace is less of an operational problem today than it is expected to be in the future. The future NAS is intended to have increased space launch and re-entry operations. These types of operations will require the ability to activate and deactivate SUA in real time for the purpose of keeping Reusable Launch Vehicles (RLV) and domestic flight operations separate.[3]

In addition to the predicted increases in SUA airspace, the civilian air traffic density is also expected to rise and, as a result, the almost 25% of the airspace that falls within some type of restricted use airspace[4] will be valuable in reducing congestion and density. It has been determined that the operational cost for the entire airspace is reduced when the dynamic use of SUA is implemented (Appendix G). A decision support tool could support both the lost and gained airspace problems associated with SUA and be instrumental in making effective use of future flexibility in SUA management. This would provide a basis upon which to define future SUA regulation and operational constraints.

Airlines have identified the optimal time for identification of SUA availability as 1-2 hours before departure.[5] Though this would support better strategic planning during the pre-departure flight planning process, a decision support tool that supports the dynamic negotiation of SUA activation/de-activation would allow for increased efficiency in the use of this airspace after flights have departed.

Additional comments about SUAs are found in Appendix G. Research needs to be done to determine the best way to notify the Flight Deck, AOC, and service providers of SUA real-time status and schedules.

---

[3] Kuchar, James K. "Integration of Reusable Launch Vehicles into Air Traffic Management, Phase I Final Report, NEXTOR Research Report RR-97-7," November 30, 1997, Blacksburg, VA.

[4] Approximately 18% of the CONUS area is under an SUA and 7% of the area is under other restricted use constraints (e.g., Controlled Firing Ranges).

[5] Bayles, S. "1997 Field Visits Air Traffic Service Plan," MITRE/CASSD, June 1997.

2.1.1.3. Case 3: Airspace Complexity Increase

On June 29, 1999 there was a severe loss of airspace capacity in Boston Air Route Traffic Control Center (ARTCC) region of control caused by a line of storms from Maine to parts of New York. The Boston ARTCC in Nashua, NH could not accept traffic from surrounding ARTCCs or foreign Oceanic controllers. The amount of airspace they had available due to weather was minimal and affected operations at both Cleveland and New York ARTCCs and arriving transatlantic flights.

There were three difficulties faced in this instance. Loss of airspace to the storm front, an unpredicted increase in traffic complexity caused by re-routing to avoid the storm, and a reduction in handoffs accepted by Boston TRACON due to its reduced capacity (caused by the weather). The dramatic loss of airspace to weather and the subsequent complexity increase equates to a total reduction in the airspace capacity. Complexity increases can be caused by many factors, not just weather in surrounding areas, but the impact is the same. Traffic must be diverted to relieve the load on the impacted sectors.

2.1.2. Problem 2: Gained Airspace

The objective is to use newly available ("gained") airspace to achieve increased benefits by both reducing airspace complexity (i.e., by strategically redirecting flights away from congested airspace) and allowing greater user flexibility.

The benefits of increased airspace availability are achieved by early attention to the changes. An alert of airspace availability can initiate a process of assessment, collaboration, and resolution. There may be no urgency to use the gained airspace, but the benefits should be identifiable and available to the user and service provider.

Factors: The gained airspace factors are exactly the opposite of those that cause lost airspace. Specifically:

1. **Weather:** Weather has changed so that airspace is suitable for flight operations where previously it was not.

2. **Special Use Airspace:** An SUA is de-activated that was previously active by the DoD or controlling agency.

3. **Airspace Complexity:** Airspace complexity has decreased in an area.

The gain of airspace for one user may be the loss for another. For example if forecasted convective activity has simply moved to another location, then it may benefit some flights and necessitate route changes for others. However, the gain of airspace and the corresponding loss are still distinct and are handled differently.

2.1.2.1. Case 1: An SUA Schedule Has Changed Releasing Airspace

If a block of SUA is not going to be utilized by participating military aircraft during a specific time period, the controlling agency may contact the local civilian controlling agency to release the SUA. For example, in New Mexico, Cherokee Control is the military Radar Approach Control (RAPCON) associated with the White Sands Missile Range and the associated restricted areas. Albuquerque Center is the civilian ARTCC controlling agency in effect when the range is not active. The unscheduled de-activation of an SUA may or may not be disseminated to users by a Notice to Airmen (NOTAM). NOTAM delivery to the pilot requires initiative by either the responsible controller, pilot, or the AOC. In either case, it is common that such information is not known.

Normally local Cherokee Control will contact the military liaison at Albuquerque ARTCC (ZAB) and advise that the WSMR is not active and the airspace is available for civilian use. This information is passed on to all sectors within ZAB, all ARTCCs, the Air Traffic Control System Command Center (ATCSCC), and AOCs. This is an example where two local facilities are concerned about one area of Special Use Airspace. Each facility has it's own unique procedures for handling Special Use Airspace. See Appendix G for details on WSMR.

2.1.2.2. Case 2: Weather Forecast Provides Route Options

Many types of weather predictions, warnings, and route forecasts are produced throughout the NAS on a daily basis to notify airspace users and service providers about potential adverse conditions that may develop throughout the day. For example, significant meteorological information (SIGMETs) and center weather advisories (CWAs) are issued so that service providers and airspace users can plan accordingly. Most flight planners and dispatchers plan routes avoiding areas of significant weather. The root of this problem is if the forecasted weather events that were used during the planning phase do not develop as predicted, then the traffic flow will not reflect what the users prefer and will most likely not conform to the TMU's desired traffic pattern (since the flight plans will not reflect non-weather effected plans). There needs to be a way to capitalize on the unexpected availability of this airspace.

2.1.3. Problem 3: Request for Route Modification

Preferential routings are accommodated if SUA, capacity, and weather permit. Commonly, the controller accepts a preferred routing change that has undesirable consequences. This occurs when the preference is developed (by the user) without knowledge of the future NAS status and the controller does not have the predictive ability to anticipate future initiatives and complexities correctly. For example, a route modification may exacerbate sector loading beyond the sector controller's awareness. Emphasis on the use of preferential routing and free flight in the future makes this a problem of continuing interest.

Factors: The undesirable consequences of re-routing problems are caused by incomplete consideration of the impact of the change. These factors include incomplete consideration of the current state of the NAS by the requester.

2.1.3.1. Case: Requested Route Causes Excess Sector Loading

The standard routing from LAX to DFW is south of WSMR, as explained in section 2.1.1.1. Figure 1 shows such a routing. The AOC may request routing to the north of WSMR to accommodate a north arrival into DFW. The impact of this routing change is not known by the AOC when making this request. This request may be disallowed based on airspace complexity considerations. This case is examined in further detail in Section 2.2.3.3.

2.2. Concept Definition

In developing an operational concept to address the problems and issues identified above, the following basic principals were adhered to:

- Focus on strategic solutions, but incorporate decision support tool supported tactical solutions for short time horizon (i.e., short lead time) dynamic events
- Solutions should be primarily ground based, to allow for acceptable integration with current NASA work in developing Transition airspace DSTs
- Develop an operational concept that addresses all of the identified problems, not independent solutions for each problem, to eliminate the need for multiple DSTs within the same environment
- Any proposed DSTs must either integrate with current NASA Transition DSTs or be an extension of these DSTs, since ultimately both concepts (and DSTs) must coexist within the same airspace and be used by the same controllers
- Collaboration with users (AOC, pilots, etc.) should be incorporated, where appropriate, to follow industry trends in supporting user flexibility within the National Airspace System (NAS)
- Solutions should leverage the work done by NASA in the development of Transition Airspace DSTs to minimize development time of new tools for Constrained Airspace

Based upon the above criteria and on the nature of the Constrained Airspace problems identified, it was decided to extend NASA's Airspace Tool (AT) concept[6] to develop an

---

[6] Vivona, et al, "A System Concept for Facilitating User Preferences in En Route Airspace," NASA Technical Memorandum 4763, November 1996.

operational concept for Constrained Airspace solutions. The goal of the AT is “to facilitate user preferences for en route flights that are not inhibited by localized, highly dynamic traffic constraints, generally for aircraft found outside high-density traffic areas and/or not transitioning to terminal airspace.” To achieve this goal, the AT will “detect and resolve conflicts with a time horizon (approximately 20 to 25 minutes) that is longer than the decision-making time horizon used by sector controllers.” By focusing on efficient resolutions for conflicts that the controller is not currently concerned with (e.g., one or two sectors away), the AT facilitates more strategic conflict resolutions. The idea is to locate the AT at either each Area Managers desk (AT responsible for a single area) or possibly within the Traffic Management Unit (AT responsible for an entire ARTCC). Solutions developed by the AT would be relayed to an appropriate sector controller for implementation.

The AT is focused solely on the interaction between aircraft (i.e., conflict prediction) and is limited in effectiveness to just a few sectors (based primarily on the degradation of trajectory prediction accuracy with distance and the need for high levels of accuracy to predict aircraft conflicts correctly). The proposal here is to use the same basic building blocks of the AT,[7] specifically the trajectory generation capabilities of CTAS, to identify:

1. Impact of lost airspace on an aircraft’s current trajectory
2. Potential benefits of trajectory changes due to newly available airspace
3. Long term impact on an aircraft’s trajectory of accommodating a user requested routing change

The Constrained Airspace problems often rely on larger time horizons than just a few sectors to be efficiently resolved. This is mainly due to the obstacles being avoided or the newly available paths encompassing large areas. In the case of avoiding lost airspace, waiting to reroute until the subject aircraft are in an adjoining sector may still require a significant deviation to avoid the airspace. A deviation several sectors earlier could have required significantly less deviation. In the case of gained airspace, waiting until the adjoining sector may mean that a significant deviation from the desired path has already occurred and the amount of benefits achievable has been reduced.

Constrained Airspace problems also tend to focus on effecting groups of aircraft, rather than just aircraft pairs. This is rather obvious for the lost and gained airspace problems, but is also true for the routing change requests. For example, the request is for all aircraft going along the southern route around the White Sands Missile Range SUAs to DFW to go on a route north around the SUAs, not just a single aircraft. Because the time horizons are on the order of several sectors and groups of aircraft are being effected, the concept is to design a DST for the Traffic Management Unit. Since most of the problem resolutions

[7] It should be noted that the building blocks of the AT are also the building blocks of NASA’s Sector Tool, User Preferred Routing (UPR) Tool, En Route Descent Advisor (EDA), and all of the CTAS based tools.

will be implemented through the sector controllers (there is the potential for collaboration with Airline Operations Centers, but this would most likely not be an initial implementation) and some problems may arise with little warning, it is expected that DST support is also required at the sectors. The interaction between the traffic management unit DST and the sector DST is modeled on the AT's interaction with the En Route Descent Advisor (EDA).[8] To simplify the following discussion, the Constrained Airspace DST will be referred to as CAT (Constrained Airspace Tool) and will be assumed to be situated within each ARTCC's TMU. Corresponding parts of CAT will be assumed to exist at the sectors, though this functionality would more likely be integrated with the User Request Evaluation Tool (URET), EDA or another NASA en route sector tool. Since some desired benefits may require the impact of events occurring in adjacent ARTCCs, it will be assumed that all ARTCC TMUs are equipped with CAT. As in the case of EDA, AT, and the other NASA en route tools, the boundary between ARTCCs will not theoretically impact the functionality of CAT (other than availability of data), but the procedural relationship between the facilities must be accounted for when developing inter-facility procedures.[9]

2.2.1. High Level Benefit Mechanisms

At a high level, the concept is to provide Traffic Management Coordinators (TMCs) with early notification of advantageous/disadvantageous events and increase the support provided in developing strategic solutions to these problems. The specific benefit mechanisms are best described in the context of the problems they are addressing.

<u>Lost Airspace</u>

When confronted with the loss of a section of airspace, either through SUA activation (scheduled or unscheduled), the formation of inclement weather (severe turbulence, thunderstorms, etc.), or excessive traffic complexity, the need is to modify the trajectories of affected traffic around the lost airspace. The goal of CAT is to identify the projected loss of the airspace as early as possible, identify the affected flights and to support the TMU in developing the most efficient trajectory modifications. Initially, this means developing plans with minimal deviations from the flight's original flight plan (or identified user preference). Ultimately, collaboration between the TMU and the impacted users (e.g., AOCs) will allow the airlines to have a hand in selecting appropriate trajectory modifications based on their economic desires.

<u>Gained Airspace</u>

---

[8] In Vivona, et al, AT interacts with a tool called the Sector Tool (ST). ST functionality is now a part of the EDA concept.

[9] Multi-facility issues for similar functionality within the TMU has been explored by MITRE/CAASD for their CRCT project. The relationship of CRCT and CAT will be defined within section 2.3 "Related Research and Development" in this document.

When a section of restricted airspace becomes available for general traffic, either through SUA de-activation (scheduled or unscheduled), the dissipation of inclement weather (severe turbulence, thunderstorms, etc.), or the dissipation of excessive traffic complexity, there is an opportunity to utilize this newly available airspace to gain benefits for the users and the service providers. Unlike the lost airspace problem, where the identification of the affected flights is relatively simple, the goal of CAT in the gained airspace problem is the identification of flights for which a reroute through the newly available airspace actually achieves a benefit. By determining appropriate measures for the user benefits (e.g., reduced travel time, fuel, or distance) and the service provider benefits (e.g., reduction in overall airspace complexity), the tool will be able to provide advisories for the TMU for flight modifications (e.g., reroutes). Again, collaboration with the users during this process will facilitate user flexibility when airspace constraints are removed.

An interesting potential benefit of using a DST like CAT in analyzing the benefits of gained airspace is the potential to use it in a "what if" or provisional capability. In this manner, the TMU can assess if significant benefits could be gained by the de-activation of an SUA at a future time. If CAT shows a significant benefit achievable, the TMU could then try to negotiate the de-activation of the SUA for a period of time just long enough to gain the benefit. This would make CAT an enabling technology for collaborative activation/de-activation (i.e., dynamic use) of SUA.

Route Request Evaluation

Where the goals of the Lost and Gained Airspace solutions are to deal with the impact on flights by a change in state of the NAS, the goal of the Route Request Evaluation is to facilitate user requests (or preferences) by evaluating their impact on the NAS.[10] Through the near future, users will make requests with only a fraction of the data required to understand the full impact of their request. Specifically, the user is often not aware of the traffic and resource constraints of air traffic when making specific routing requests. The goal of CAT is to allow the TMU to identify when acceptance of a routing change request will cause the flight to enter a constrained area, thereby causing the flight to incur unexpected delays that will remove the benefit desired by the user. Since the user has one perspective and the TMU has another, collaboration between the two is necessary for this benefit to be achieved. CAT will enable and facilitate this collaboration.

[10] This need to evaluate user requests, against traffic management constraints, complements the conflict (and SUA) probing of user requests (as handled by such systems as the User Request Evaluation Tool or URET). Conflict probing is a much shorter time horizon (tactical) planning effort than proposed here.

2.2.2. System Functions

There are four steps required to solve Constrained Airspace problems: identification, dissemination/notification, resolution, and implementation (Figure 2).

Identify
- Event Location and Time
- Prepare Data for Dissemination

Disseminate and Notify
- Classification of the Event
- Dissemination and Notification
- Log Actions
- Track Responses
- Reiterate As Needed

Problem Resolution
- Identify Actions Required
- Initiate Collaboration
- Planning Support Functions
- Select Solution

Implement

Figure 2 Four Steps in Problem Resolution

Each of these steps requires different functionality from CAT for the different types of Constrained Airspace problems.

<u>Identification</u>

Identification is a two step process: determine that an "event" has occurred which will impact flights and identify the flights being impacted. For Lost/Gained Airspace problems, the events are:

1. Future SUA activation/de-activation

2. Future and current hazardous weather formation/dissipation

3. Future and current sector traffic complexity exceeding/dropping below acceptable levels

For Route Change Requests, the event is the receipt of the request. This request could take several forms, including a single request for a single aircraft or a “standing request” for all aircraft of a particular type over a specified period of time.

Identification of the SUA activation/de-activation event requires CAT to be notified of both scheduled and unscheduled SUA activation/de-activation. This could be accomplished through manual entry by the TMU, but an automated process would reduce both workload and possibility of error. For collaboration with users, this identification process would also include the distribution of SUA status to the AOCs.[11] The identification of hazardous weather events requires CAT to have a method for identifying the size and severity of weather cells and turbulence. The identification of traffic complexity events requires an algorithm for determining traffic complexity based on traffic load and other factors. Routing change request events occur when the request is received. This process could also be manual or automated through connections to AOC automation.

Once an event has been determined, the magnitude (e.g., size of area impacted) and time duration must also be determined. SUA changes and route change requests include the area impacted and scheduled time duration. Weather and traffic complexity events require algorithms to predict the area impacted and time duration. For weather cells, this information comes from forecasts of weather magnitude and movement. For traffic complexity, the area impacted will be identified sectors (similar to the concept of a sector going “red” based on Enhanced Traffic Management System data) and the time duration will be based on aircraft trajectory predictions.

After the event has been completely identified in magnitude and duration, the flights impacted must be identified. Similar to the AT and other NASA en route tools, CAT will use CTAS trajectory prediction algorithms to identify which aircraft are impacted by the events. For lost airspace events, this involves predicting when an aircraft trajectory penetrates the affected area and determining if this penetration occurs during the time duration of the event. The uncertainty of when an aircraft will enter an affected area of airspace (even if the area is changing, as is the case for weather) is not expected to be as large as the uncertainty in identifying when two aircraft close to within a distance smaller than the separation standards. Therefore, it is expected that lower prediction accuracy will be acceptable for CAT than for a conflict probe (e.g., AT) and that the larger time horizons required by CAT will be achievable. The lack of predictability for satellite departure times may be more of a significant issue. Study is required to confirm that the prediction accuracy issues are resolvable.

---

[11] The identification of NAS status changes (of which SUA is one example) is a general requirement for many advanced user collaboration concepts. The idea is that by distributing this information to the users, users will be able to modify their aircraft routing to avoid negative impacts of NAS changes (i.e., increase the users flexibility in handling these changes). For more on this topic, see Green, S., et al: “Enabling User Preferences Through Data Exchange,” AIAA Guidance Navigation and Control Conference, New Orleans, LA, 1997.

In the case of Gained Airspace events, the identification process is more complex. As opposed to identifying which flights are impacted by the event, Gained Airspace events require the identification of flights that do not require trajectory modifications, but could benefit from a trajectory change. There are several methods that could be used to identify these flights. In the case of SUA airspace, which has static boundaries, any flights flying between identified city pairs could be candidates for rerouting if an SUA is de-activated. The collection of city pairs and related SUAs would be a subject for further study. Since SUA areas are well defined, the flight profile/object developed by a user could include specific SUAs that the user identifies as desirable to use, if available. For weather and traffic complexity events, which do not always impact the same geographic area, all aircraft predicted to fly within a specified distance of the dissipated weather area or sectors with newly reduced complexity could be checked to see if benefits could be gained through utilization of the gained area. The development of algorithms to identify aircraft to benefit from gained airspace is a large area for research. This is an area where collaboration with user automation would be highly desired, if not required.

For "standing" route change requests, those aircraft that meet the definition of the request (e.g., all aircraft flying south of White Sands Missile Range and arriving at DFW) will be identified. For single aircraft requests, the identification process is trivial.

Dissemination/Notification

The dissemination/notification stage of the process is relatively straightforward for CAT. After the event and the flights impacted are identified, the TMC monitoring the system must be alerted. This will be accomplished through a display similar to CTAS's Planview Graphical User Interface (PGUI).

For Lost and Gained Airspace events, the impacted airspace will be displayed. SUA boundaries will be highlighted when the area is active (e.g., colored red for non-transgression) and will change color when the airspace is gained (e.g., green). Weather information should be color-coded for easy identification of severity and type (e.g., turbulence versus thunderstorms). Traffic complexity sectors should also be color coded to identify the level of traffic complexity above a certain threshold. With the possibility of multiple events occurring simultaneously, a human factors study of the man-machine interface should be conducted to create the best interface.

Along with the events, the impacted aircraft should also be highlighted on this interface.

Resolution

Since all of the problems involve trajectory changes as their solution, the main resolution method will be to use manual and automated methods (e.g. manual and automated rerouting) to identify solutions to the identified problems. Manual solutions will follow the basic CTAS methodology for provisional ("what if") solutions. This will allow the TMC to enter trajectory modifications for the identified aircraft (e.g., flight plan amendments) into CAT and evaluate the impact of the changes without affecting other controllers. The TMC will modify these trajectories until an acceptable solution is developed. Automated trajectory generation methods will algorithmically identify an acceptable solution and present this to the TMC as a trajectory change advisory. The TMC will still be able to manually modify the advised trajectory change if it is not the TMC's desired solution. As user collaboration is added to the CAT concept, resolutions will require user input and, in the extreme, user developed resolutions. When users perform the resolutions, the TFM functionality of CAT will focus more on the identification of problems and the acceptance/coordination of the user's desired resolution.

For Lost Airspace problems, the goal of the CAT resolution process is to identify a modification to the impacted aircraft's trajectory that minimizes the required deviation from the aircraft's current route. This method assumes that the aircraft's current flight plan route is the user's preferred route for that aircraft. Automated and manual techniques will focus on minimizing additional fuel burn, distance flown, time flown, or other metrics representing the impact of the maneuver on this flight. Research on the appropriate metrics must be performed, but even a simple air distance flown calculation should provide some benefit. Collaboration with users to determine how the user wants to handle the lost airspace would allow user flexibility during this process. By alerting the TMC upstream of the need to divert traffic around a piece of lost airspace, required deviations would be minimized.

Though the identification processes for Lost and Gained Airspace events is significantly different, the resolution process is basically the same. Instead of trying to minimize deviations from the aircraft's current route of flight, in the Gained Airspace problem, CAT is attempting to find a new trajectory that maximizes the potential benefits of changing the trajectory. Similar metrics (such as distance or time flown) are still being used, but now the focus is on reducing this metric from the original route of flight value. Gained Airspace problems require some form of collaboration with the user (at least with the pilot) because in these cases, the trajectory change is not mandatory.

For Route Change Requests, the resolution process starts by identifying whether the requested route change would negatively impact the aircraft or operations. The most obvious negative impact would be an increase in traffic complexity along the proposed route, either created by the addition of this/these aircraft or existing prior to the request. Whether the route change is received from the flight deck or the AOC, CAT would allow the TMC to identify when the acceptance of the route change request would lead the aircraft to incur delay downstream, thereby possibly negating the intended benefit assumed by the user when making the request. Since neither the TMC nor the user knows the entire story (the user knows the preference, TMC knows the current and future NAS status), collaboration between the two is required. By allowing the TMC to predict the impact of the route change on the airspace and on the aircraft, the correct decision on whether to change the aircraft's route can be made. If the request were made by the flight deck to the controller, CAT would work collaboratively with the sector controller DST to alert the controller to the possible downstream impediment and that the problem would be resolved in coordination with the TMU. In later versions of CAT, current and future

NAS status information would be collaboratively shared with the user to reduce the request for a preferred route that creates negative NAS impacts.

Implementation

In all of the Constrained Airspace problems, the solution involves a change in the aircraft's trajectory. This trajectory change must be coordinated with the appropriate sector(s) and implemented through clearances by the sector controller who is responsible for that flight. Non-standard clearances should not be required to effect the desired solution. Autocoordination of TMC generated solutions for sector implementation would occur in the manner proposed in the AT/ST concept[12] and/or in the manner that is currently applied for the URET autocoordination capability.

2.2.3. Example Scenarios

The following example scenarios are provided to help clarify the use of the Constrained Airspace Tool. A single basic scenario is presented that reflects the characteristics of each type of problem. The scenario involves traffic within Albuquerque ARTCC that is flying from the West Coast (the route shown is from LAX) to DFW airport. ZAB contains the large SUA for White Sands Missile Test Grounds in the middle of the ARTCC. Traffic is typically directed south or north around WSMR since this SUA is almost continually active. All of the scenarios assume that the CAT system resides in the ZAB TMU. Multi-facility issues are not addressed and user collaboration is minimized in the scenarios to reflect a possible initial implementation of CAT. All collaboration with users is assumed to be verbal over common land lines. Only a single flight is presented, but the use of the tool could easily be extended to banks of aircraft.

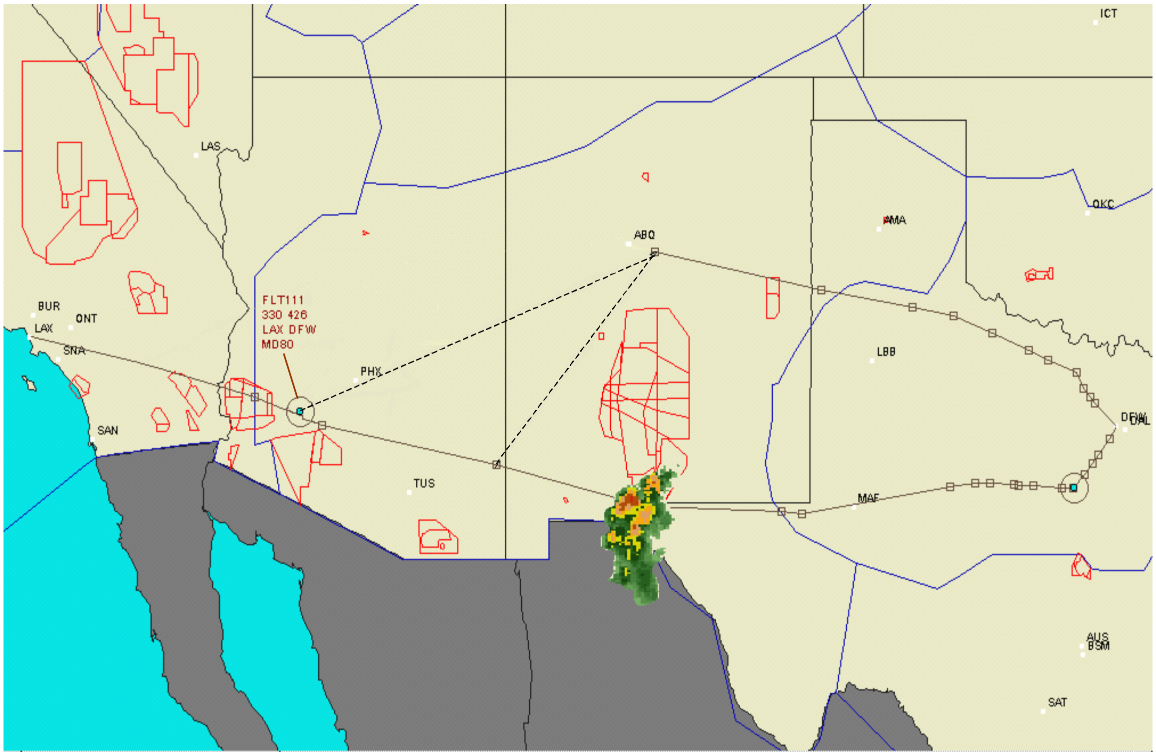
2.2.3.1. Lost Airspace Scenario

In this example scenario, Flight 111 is currently routed south of WSMR on its way to DFW. The TMU has been alerted to inclement weather activity in the southern part of the ARTCC.

A notional representation of the CAT display is shown in Figure 3 . CAT is predicting a weather cell formation on the southern edge of WSMR that will prohibit flying through that airspace in 1 hour. After that time, southerly traffic will require rerouting north of the SUA (rerouting south will require prohibitive distances into Mexican Airspace). Flight 111 is predicted to be the first aircraft to fly through the impacted airspace after the airspace will be lost. The TMC reroutes Flight 111 on a path north of WSMR.

---

[12] Vivona, R.A., "A System Concept for Facilitating User Preferences in En Route Airspace," National Aeronautics and Space Administration, November 1996.



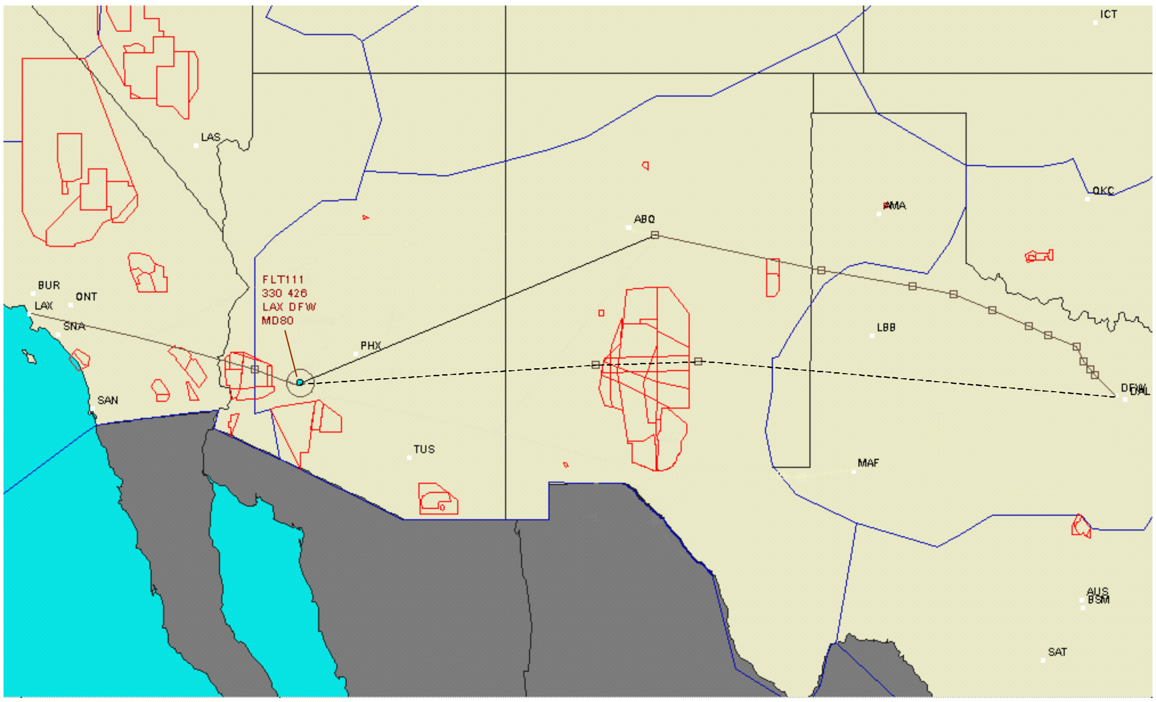
Use of *Flight Explorer* Graphics courtesy of Dimensions-International, Inc.

Figure 3 CAT Resolution to A Lost Airspace Event

Because of CAT's ability to show the impact of predicted inclement weather on the current traffic in the ARTCC, the TMC is able to identify the first aircraft to be impacted by this weather and to start the rerouting process earlier than without the support of a DST. The TMC can begin the process of rerouting Flight 111 and the aircraft behind it that will also penetrate the lost airspace due to weather. Without CAT, the reroutes would have begun much later, requiring a more extreme increase in aircraft distance and time flown. CAT will allow these reroutes to be manually or automatically generated and probed for increases in complexity to the north of WSMR due to the unexpected traffic increase. If the area north of WSMR starts to exceed the allowable traffic complexity, CAT will identify this situation and support the TMC in developing an integrated solution that reroutes a minimum number of aircraft from the south and redirects some of the northern traffic to reduce the northern complexity situation (i.e., avoid creating a lost airspace problem in the north by trying to solve the lost airspace in the south).

2.2.3.2. Gained Airspace Scenario

In Figure 4 , Flight 111 is flying a route north of WSMR when a corridor of airspace within WSMR is de-activated. The WSMR SUA may de-activate this corridor instead of the entire SUA to support operations in ZAB.[13] Flight 111 could be the same aircraft as in the Lost Airspace example that has been rerouted from the south (the corridor is often opened when there are weather problems) or this could have been Flight 111's original path.



Use of *Flight Explorer* Graphics courtesy of Dimensions-International, Inc.

Figure 4 CAT Resolution to A Gained Airspace Event

When the corridor in the SUA is identified, CAT identifies which aircraft within the ARTCC would benefit from the gained airspace. If Flight 111 were continuing north to Denver ARTCC, then the opening of the airspace would not have an impact. Since the aircraft will eventually turn east to proceed to DFW, the ability to "cut through" the SUA provides a reduction in the flight's "air" distance and flight time. CAT will identify all aircraft that would benefit from this available airspace, while probing the reroutes to check for traffic complexity within the corridor. In this way, CAT will support the TMC in redirecting traffic through the available airspace without creating a lost airspace problem within the corridor. When the TMC identifies an aircraft that can gain benefit by

---

[13] See Appendix G.

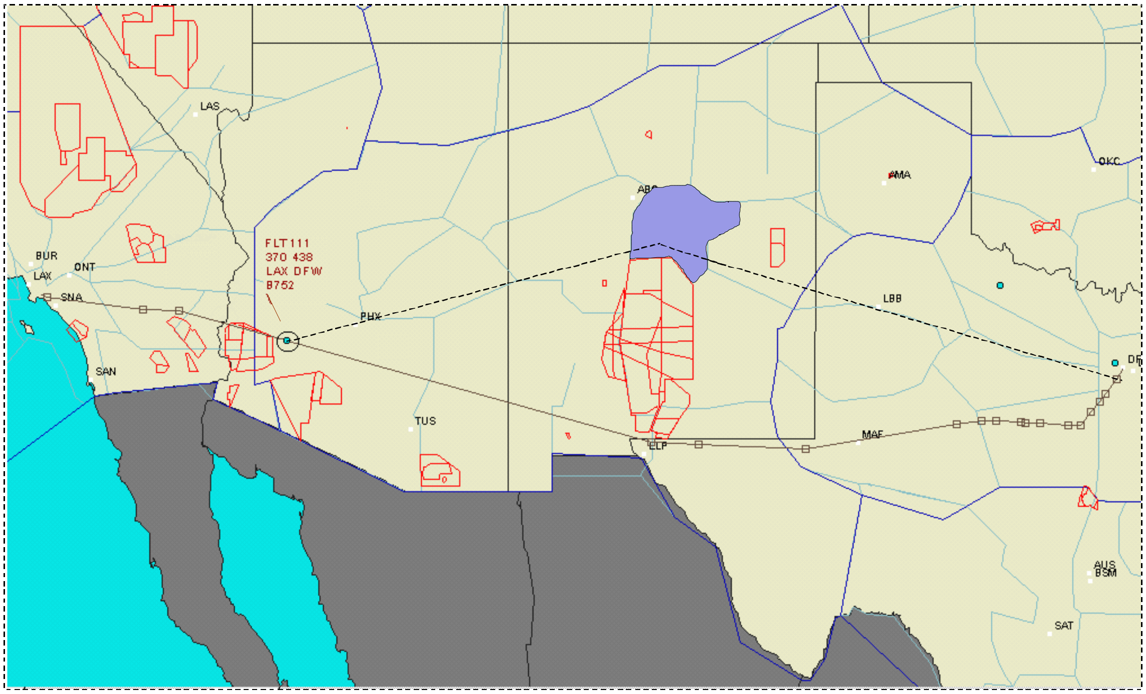
rerouting through the SUA corridor, this route change is coordinated and implemented through the controller who currently owns the aircraft.

Because, in this example, the only reason to redirect the traffic through the corridor is to gain user benefit, the user should be collaborated with to determine if the rerouting is desired. In certain cases (like this one), the answer may be clearly evident and can be coordinated up front (i.e., the airline saying that this is OK for a normal procedure without having to clear it with them). If the TMU were using the open corridor to relieve congestion to the north of WSMR, this collaboration would not be required.

2.2.3.3. Request for Route Modification Scenario

In Figure 5 Flight 111 is currently on a path south of WSMR, but has requested a reroute to the north. This reroute may be due to favorable winds or because the aircraft wishes to arrive at DFW through a northern arrival gate (e.g., to gain access to a preferred runway). The sector controller receiving the request inputs a provisional requested route change into the sector DST and is alerted by CAT that there is a potential problem with this route request. The TMU, already alerted by CAT about the requested route change, uses CAT to evaluate this provisional solution and identifies that there is already marginal traffic complexity north of WSMR and that the addition of this aircraft would increase traffic complexity above desirable levels. The TMC alerts the controller (who alerts the pilot) that this reroute could cause the aircraft to incur extra delay due to the traffic situation north of WSMR. The controller and pilot decide that the route change would not achieve the desired benefit, so the route change request is removed.

A similar example could be developed where the interaction occurs between the TMU and AOC when the request for a route change originated with the AOC. In that example, the pilot and sector controller would not need to be involved if the request were mutually rejected, as in the example above. If the request were acceptable, then the pilot and controller would be involved in either the implementation of the route change or the rejection/postponement of the request due to tactical concerns by either the pilot (e.g., ride/safety concerns) or the controller (e.g., potential conflicts).



Use of *Flight Explorer* Graphics courtesy of Dimensions-International, Inc.

Figure 5 CAT Resolution to A Route Change Request Event

By evaluating the impact of user requests and enabling the TMC to provide the AOC with insight into the projected impact of the request, CAT can provide benefit to both the users (avoid the extra travel distance and incurred delay) and service providers (reduction in potential traffic density).

2.3. Related Research And Development

The proposed operational concept for CAT leverages and extends existing capabilities being developed over a broad spectrum of technologies. These technologies include advancements in weather prediction and reporting, development and implementation of dynamic density measures to identify airspace complexity, dynamic re-sectorization, communications technology, and concepts for increased collaboration.

This section provides a brief summary of the current state of the technology in each of these areas as it relates to the CAT concept.

2.3.1. Weather Prediction and Reporting

Weather events affect all three problem areas identified: Lost Airspace, Gained Airspace, and User Requested Route Changes. Airspace is lost because some weather events prevent aircraft from operating in portions of a sector(s), and because weather-induced re-routings contribute to increased airspace complexity and higher controller workloads. Airspace can be gained when a disruptive weather event ends or moves out of the affected area (which may in turn disrupt other portions of the airspace). User requested route changes are often made to avoid weather for safety or efficiency issues, e.g., to avoid turbulence, find an opening in a line of convective activity, or take advantage of more favorable winds. In this paradigm, accurately predicting the end of a weather event will be as important as predicting the beginning of the event.

In the en route environment, the major sources of weather disruption are 1) convective weather, especially a line of thunderstorms blocking a sector(s); 2) turbulence, in the summer often associated with convective weather and in the winter with strong shear in the vertical profile of winds near the jet stream; orographic effects, such as airflow over the Continental Divide, also produce turbulence; 3) icing, and 4) very strong jet stream winds. The first two factors are likely the dominant sources of adverse effects on en route operations due to weather.

The look-ahead time horizon for weather information to support the CAT DST is likely on the order from 20-30 minutes to a few hours. This requirement straddles the roles of nowcasting versus forecasting tools, and both will likely be needed to provide information to the CAT DST. Nowcasting tools generally cover the period 20-60 minutes into the future. They rely on objective analyses of current conditions that are then extrapolated to expected future conditions based on statistical or trends analyses. The Integrated Terminal Weather System (ITWS), being developed for operations in the terminal area, uses nowcasting tools to predict the evolution of weather events disrupting operations in a Terminal Radar Approach Control (TRACON). Numerical weather prediction models solve the basic physical equations governing atmospheric motions and thermodynamics to forecast the weather several hours to several days in advance. Several such models are currently in use in the NAS (see below) and research and development in this area continues, but should be accelerated in terms of its ATM applications (integration with DST capabilities such as CAT). Such an accelerated focus on ATM could be facilitated by NASA with a modest investment (to focus outside meteorological expertise/resources on CAT applications) and modest technical interchange between domain experts (NASA ATM developers and meteorological researchers)."

The average duration of a flight in the National Airspace System is two hours. For this reason, weather constraints that are effecting en route operations, especially lost airspace, can affect decisions by the AOC's and ATC regarding execution of ground delay programs. Hence, information provided by the CAT DST can affect flight operations for aircraft that are not yet airborne. This is an area where collaboration between the AOC's and ATC can be very beneficial in terms of maximizing system capacity and efficiency and managing costs to the airlines.

The impact of weather on constrained en route airspace is similar to the impact on airports. Weather events in large terminal areas can disrupt operations in the en route environment, creating increased complexity and congestion. For example, convective weather or reduced ceiling and visibility conditions cause airport throughput rates to be substantially reduced relative to those available during visual meteorological conditions.

When this happens, a TRACON may not be able to accept as many aircraft from an ARTCC as planned. This can lead to increased workload for ARTCC controllers and increased complexity in en route sectors as ATC is forced to deal with unplanned re-routings, speed reductions and maneuvering, and diversions. Although these are primarily related to the transition between en route and terminal operations, the impact is general and covers all aspects of airspace operations.

Some of the key technologies that are deployed or expected to be operational in the next few years that could provide important weather information for the CAT DST include the following:

- **Weather and Radar Processor** (WARP). WARP is a meteorological workstation being deployed in the Center Weather Service Units (CWSU) in each ARTCC. WARP will give CWSU meteorologists a tool that can help them generate improved weather information that in turn will allow traffic planners to make better decisions regarding expected weather disruptions in Center airspace. WARP will allow CWSU meteorologists to prepare mosaics of Next Generation Radar (NEXRAD) reflectivity data and to overlay supporting weather information like lighting strike data, satellite imagery, and gridded and graphical weather information. In its initial "Stage 0" implementation, WARP products will be available to CWSU and TMU personnel for briefing and planning purposes. Future implementations of WARP (Stage 1, Stage 3) are designed to allow weather displays to be presented to controllers.
- **Rapid Update Cycle** model (RUC). The RUC is a numerical weather prediction (NWP) model run by the National Weather Service (NWS) at its National Center for Environmental Prediction (NCEP). The RUC combines objective analyses and short-term prediction tools to prepare gridded data sets of surface and upper-air meteorological conditions that impact aviation operations. The current version of the RUC (RUC-2) is run at NCEP every hour on a 40-km grid covering the continental U.S., and produces an analysis of current conditions and hourly forecasts out to 12 hours. The RUC is a hydrostatic model, which means that convective activity can not be forecast explicitly but must be parameterized from available information. The RUC is the current source of gridded upper-air wind data used by the trajectory synthesis algorithms in CTAS.
- **Aviation** model (AVN). The AVN is a relatively coarse-grid National Weather Processor (NWP) model that provides forecasts of global weather conditions. Models like the AVN are typically run twice daily, and forecasts are usually issued in six to twelve hour intervals for periods as short as six hours to as long as several days. NWS meteorologists use these forecast products and other available information to prepare advisories and alerts for weather conditions that may adversely affect aviation operations (e.g., SIGMETS, convective SIGMETs). AVN wind data are used by airlines to plan optimum routings, especially for transcontinental and international flights.
- **Aviation Gridded Forecast System** (AGFS). The AGFS is a data management and analysis system. It consists of three-dimensional, time-varying gridded data sets of

analyzed and forecasted weather conditions that affect aviation. For example, all of the RUC output is available to aviation meteorologists via this system. When complete the AGFS is supposed to include software tools that will allow meteorologists to automatically prepare and distribute gridded fields of Aviation Impact Variables (AIV's) such as expected areas of convective activity and turbulence. The first group of AIV algorithms being developed are supposed to predict areas of icing and turbulence, but AGFS researchers have run into problems developing these algorithms, so that the only AIV's currently in the AGFS data base are the Airman's Meteorological Information AIRMETs and SIGMETs prepared by Aviation Weather Center meteorologists.[14]

- **Meteorological Data Collection and Reporting System** (MDCRS). MDCRS data include upper-air wind and temperature data measured by commercial aircraft. An increasingly larger portion of the commercial aircraft fleet is reporting MDCRS data. The aircraft data are used to help initialize RUC forecasts, and they have been shown to produce improvements in forecast accuracy, especially of upper-air winds. A few hundred aircraft will soon begin reporting turbulence information, based on measurements of turbulent kinetic energy eddy dissipation rates. Plans are underway to also equip some aircraft to measure atmospheric moisture, which could improve forecasts of icing and convective activity.
- **NEXRAD, Radar Profilers**. The NEXRAD network of Doppler weather radars provides radar coverage of most of the continental U.S. NEXRAD data are available from NEXRAD Information Dissemination Service (NIDS) providers. National Oceanic and Atmospheric Administration (NOAA) also operates a network of 32 Doppler radar wind profilers, which measure vertical profiles of winds (speed and direction). These data are used to initialize the RUC model.
- **Aviation Weather Information (AWIN)** system. AWIN is a NASA initiative currently under development to distribute graphical weather information to the cockpit in near-real time. Flat panel displays of radar reflectivity, regions where convective weather, turbulence, and reduced ceiling and visibility are expected, satellite imagery, weather maps, etc. will be available to flight crews to help improve safety and to support flight re-planning activities.

The concept of delay management through the Collaborative Decision Making (CDM) program began in the NAS in 1998. About 20 airlines, the FAA, and other industry and government groups are participating in the CDM program. CDM is a planning initiative that allows NAS planners at the Air Traffic Control System Command Center and the airlines to share information on flight schedules, traffic, and availability of airport capacity when weather disrupts operations at an airport. The goal of the CDM program is to allow the airlines to better manage their own operations to reduce the costs associated with weather delays and to maximize airport capacity during adverse weather events. As

---

[14] Personal communications between Lin Lindsey and Lynn Sherretz, NOAA/FSL.

part of CDM, the FAA and the airlines are creating AOCnet, a high bandwidth Intranet connection to share schedule and traffic information.

Only six carriers currently have their own meteorological teams within their AOC's: United Airlines, Northwest Airlines, American Airlines, Delta Airlines, United Parcel Service, and Federal Express. These groups provide customized forecasting services for their airlines and are actively involved in flight planning operations. Other AOC's get their weather information from contract service providers. Most of this information is based on NWS data and forecast products, packaged with value-added features for the airlines. Generally speaking, the six carriers with their own meteorological groups believe their forecast accuracy is superior to that of the NWS. An important element of the CAT DST will be providing shared awareness of expected weather conditions between the ARTCC's and AOC's, and developing consensus on expected forecast conditions and their impacts on the airlines.

The accuracy of the RUC and other forecast models with respect to predicting disruptive weather in the en route environment is not fully understood. Forecast accuracy always degrades with increased look-ahead times.

2.3.2. Special Use Airspace Real Time Tracking

The Military Airspace Management System (MAMS) and the Special Use Airspace Management System (SAMS) programs within DoD are ostensibly designed to provide timely information about scheduling and use of military airspace and SUA. They are being performed by Raytheon Company. These are ongoing programs and are being continually improved and enhanced through internal discussions between the government and the contractor. There is no current plan on public record for real time tracking of SUAs.[15] In particular, no there is no plan for the accurate prediction (30-120 min) of SUA activation/deactivation in support of dynamic SUA access

The FAA Capitol Investment Plan[16] program Operational and Supportability Implementation System (OASIS) is a Flight Service Station automation system that includes SUA status reporting. OASIS is not intended to be an integral part of the NAS en route automation.

2.3.3. Dynamic Density

The number of aircraft in an Air Traffic Control Sector, called the sector count, is a measure of the capacity of a sector. A sector "goes red" in Enhanced Traffic Management System (ETMS) when the sector count exceeds a predetermined value for that sector. Because the complexity of the air traffic operations in the sector are not

---

[15] Rock, Dennis, "Negotiation Automation for Special Use Airspace," AIAA Paper 1999.

[16] FAA, "Capitol Investment Plan, 1999," Washington, D. C., 1999.

directly considered in sector count, this measure is only roughly relevant to actual workload.

The Dynamic Density of a sector at a particular time is a number which measures air traffic control related workload; it is a generalization of sector count. Dynamic Density is currently a concept that a function of the number of aircraft and the complexity of traffic patterns in a volume of airspace can be formulated to succinctly, in a single number, represent the air traffic work load for that sector.

The components used in various formulations of Dynamic Density include the following 18 different values.

1. **Number of Aircraft:** The count of the number of aircraft in the sector.

2. **Traffic Density (N):** The number of aircraft divided by the usable volume of airspace (1 minute sample)

3. **Heading Change (NH):** The number of aircraft with a heading change of greater than 15^{o}(1 minute sample)

4. **Speed Change (NS):** The number of aircraft with speed change greater than 10 knots or 0.02 Mach (1 minute sample)

5. **Altitude Change (NA):** The number of aircraft with altitude change greater than 750 feet (1 minute sample)

6. **Neighbors (S5):** The number of aircraft with 3-d Euclidean distance between 0 and 5 nautical miles excluding violations (1 minute sample)

7. **Neighbors (S10):** The number of aircraft with 3-d Euclidean distance between 5 and 10 nautical miles excluding violations (1 minute sample)

8. **Neighbors (S25):** The number of aircraft with 3-d Euclidean distance between 10 and 25 nautical miles and vertical separations less than 2000/1000 feet above/below flight level 290 (1 minute sample)

9. **Neighbors (S40):** The number of aircraft with 3-d Euclidean distance between 25 and 40 nautical miles and vertical separations less than 2000/1000 feet above/below flight level 290 (1 minute sample)

10. **Neighbors (S70):** The number of aircraft with 3-d Euclidean distance between 25 and 70 nautical miles and vertical separations less than 2000/1000 feet above/below flight level 290 (1 minute sample)

11. **Angle of Convergence in a Conflict Situation:** This measure puts a higher value on converging aircraft pairs for which the convergence angle is less than 30^{o}. The basis

for this measure is that the controller is less able to judge aircraft separation when the angle of convergence is small.

12. **Number of Aircraft Climbing or Descending:** The count of the number of aircraft changing altitude in a designated period of time.

13. **Distribution of closest Points of Approach:** This value increases as the closest points of approach for converging aircraft are closer together.

14. **Level of Knowledge of Intent of Aircraft:** The value increases as the number of aircraft for which there is little or no knowledge of intent increases.

15. **Proximity of Aircraft to Sector Boundary:** The value increase as the number of aircraft near the sector boundary increases.

16. **Proximity of Potential Conflicts to Sector Boundary:** The value increase as the number potential aircraft conflicts near the sector boundary increases.

17. **Airspace Structure:** A value allocated to the particular airspace structure in use at the time.

18. **Degrees of Freedom:** A value based on the notion that the fewer the degrees of freedom that a controller has in modifying the route of an aircraft, the higher the complexity.

Each of these values is accumulated over a time period - typically between one and fifteen minutes.

Value 1, Traffic Count, is the sector count presently used in ETMS for assessing sector loading. Values 2 through 10 are the subject of analysis presented in "Airspace Complexity and its Application in Air Traffic Management" by Dr. Banavar Sridhar et al and presented to the second USA/Europe Air Traffic Management R&D Seminar in December 1998.[17] These values were variously studied by Irene Laudeman et al in a paper dated October 1998[18] and a presentation by Chris Brinton et al date August 1997[19], and the other references listed in the document bibliographies. Variants of each value

---

[17] Sridhar, Banavar, Kapil S. Sheth and Shon Grabbe, “Airspace Complexity and its Application in Air Traffic Management," MS 210-10, NASA Ames Research Center, Moffett Field, CA, December 1998

[18] Laudeman, Irene, Connie Brasil and Robert Branstrom, “Air Traffic Control in Restructured Airspace: A Study in Tactical Decision Making” (Presentation), NASA Ames Research Center, San Jose State University, and University of California-Berkeley.

[19] Brinton, Chris, Bill Pawlak, Ken Lancaster, Kim Crouch and David Rothenberg, “Air Traffic Control Complexity Research and Application” (Presentation), Wyndemere Incorporated, William J. Hughts Technical Center, August 29, 1997.

presented above have been considered in different formulations of the Dynamic Density measure.

Dr. Sridhar's work addresses the prediction of air traffic controller activity level based on the air traffic patterns. The results presented show that the factors used provide a very good predictor of future workload as is evidenced by activity.

Current work by FAA ACT 540 is to compare Dynamic Density measurements to subjective assessments of the airspace complexity by controllers. The objective of this particular study is to validate a 7 step scale of Dynamic Density with the intent of providing guidance as to whether it is appropriate to re-sectorize, add controller staff, scale back free flight options, or activate ground delay programs.[20] [21]

Dynamic Density continues to be a subject under study. No specific implementation date has been identified, but the FAA and industry has often identified this as a gap and the need for getting a dynamic density product into operational use.[22]

Neither weather nor special use airspace status is explicit in any of the values or measures that have been studied. Value number 2, Traffic Density, provides some measure of the impact of airspace lost or gained as the result of changing weather or SUA status. When airspace is lost, the density increases and when airspace is gained the density decreases. The last value (number 18), degrees of freedom, increases in the presence of severe weather and SUA closing since the lost airspace reduces the operational rerouting options available to the controller. The dynamic density measure developed by Dr. Sridhar predicts controller workload based on a revised routing plan. The measures being studies, however, do not fully address the impact of the loss or gain. It is not clear, for example, how the degrees of freedom value would be predicted before re-routing is determined or what the measure would be prior to developing a re-route plan. Additionally, adverse weather which is flyable, or lost facilities (a VOR is off or a guide slope is down) may not increase the traffic density value but may necessitate a total reduction of traffic in the area.

2.3.4. Dynamic Re-sectorization

Dynamic re-sectorization is identified as one approach to management of airspace in the future. The CAT concept could influence re-sectorization decisions (e.g. through better

---

[20] DiMeo, Karan and Parimal CTR Kopardekar, "Dynamic Density Metric Variables," FAA Technical Center, Slide Presentation, March 15, 1999.

[21] DiMeo, Karan, "Dynamic Density Joint Study Plan," FAA Technical Center, ATC-540, August 27, 1999.

[22] For example, refer to this FAA/ MITRE sponsored Technical Interchange Meeting: Heimerman, Kathryn, "Proceedings of the First FAA Dynamic Density / Air Traffic Control Complexity Technology Exchange Meeting," MT98W0000015, MITRE Corporation, McLean, VA, November 1997.

prediction of traffic loads), but its focus is not on optimal sector boundaries. Wyndemere Incorporated has done work in the dynamic re-sectorization area but do not presently have any contracts to further this research.[23] Dynamic density is a critical supporting technology necessary to facilitate re-sectorization decisions.

2.3.5. Collaboration Concept

The concept of collaboration is to help resolve problems between different groups (e.g., between the AOC, pilot, and controller) is being studied from many different directions. The web site http://atm-seminar-98.eurocontrol.fr/sessions.htm includes references to several current directions of study. Additionally, each of the papers found on this site have useful bibliographies. There are two main areas of collaboration that impact CAT directly. The first is CDM, which was described in the weather prediction and reporting section above. The other is the current prototyping. Weather information is an emphasis in the current application of CDM as is noted in Section 2.3.1, Weather Prediction and Reporting. This section concentrates on current prototyping work by MITRE called Collaborative Routing Coordination Tool (CRCT).[24]

CRCT is a set of decision support capabilities designed for use by the local traffic manager or the ATCSCC specialist. Using CRCT, the traffic manager can examine congestion and traffic flow problems by identifying a Flow Constrained Area (FCA) as a region of airspace that causes an operationally significant congestion problem. An FCA may be a sector or group of sectors, an SUA, approach control airspace, individual fixes, dynamic events like a weather cell, or a manually identified area. CRCT supports rerouting decision making by a local traffic manager in six steps.

1. Identifying and analyzing the flow problem situation

The Automated Problem Recognition (a CRCT feature) examines the traffic flow to identify congestion and weather problems. Traffic managers are able to monitor predicted sector loading in 30-90 minute time frame; alerts are generated when problems requiring attention are identified. A Flow Constrained Area is defined by the controller/traffic manager when a problem area is defined.

2. Locating Flights Involved In The Problem

When an FCA is activated the traffic manager is provided with an automatically generated representation of flights that are predicted to pass through the FCA. The display may be a plan view display showing aircraft locations and routes or a tabular list.

[23] Wyndemere Incorporated, "Initial Evaluation of the Dynamic Resectorization and Route Coordination (DIRECT) System Concept," NASA Contract # NAS2-97057, august 27, 1997.

[24] Carlson, Laurel S. and Lowell R. Rhodes, "Operational Concept for Traffic Management Collaborative Routing Coordination Tools," MTR98W0000106, MITRE Corporation, McLean, Virginia, July 1998.

The traffic manager can filter the data to include only specific categories of flights (e.g., military flights or flights with a specific destination).

3. Developing The Reroute Strategy

The traffic manager may define reroutes for specific flights using a point and click technique.

4. Evaluation Of The Reroute Strategy

When the reroutes are planned, inter-facility collaboration is initiated. Each facility involved in the collaboration will examine its sector loading and other factors. The traffic managers can modify the reroute strategy to accommodate the joint needs.

5. Coordinating The Reroute Strategy

The collaboration produces a collective reroute strategy to include specific flights and reroutes of those flights.

6. Implementing The Reroute Strategy

This jointly developed strategy is implemented by directing the controllers to give out the flight plan amendments as per current procedures.

CRCT is expected to be operational in the 5 to 10 year period. MITRE Corporation performed initial work in 1998 and 1999. There are plans to establish stand-alone capabilities at Herndon, VA and at the Kansas City center. These capabilities will function independently and will not be integrated into existing operational systems.

CRCT automatically identifies congestion and flow problems. The congestion measures are based on sector counts. A dynamic density measure has been developed to support the APR and is being studied by MITRE. The FCAs are manually identified and activated. Collaboration is defined to be between FAA facility traffic managers and does not include the flight crew, flight deck, or the AOCs. The FCA is the focus for collaborative decision making. It is assumed that suitable communications technology is available.

As such, CRCT represents an excellent technological step that can provide a good foundation for CAT concept exploration/prototyping to complement functional development. Although both CAT and CRCT activities are attempting to solve common en route "constrained" airspace problems, they complement each other in the following way. CRCT activities emphasize near-term implementation solutions (by the shear nature of the FAA/industry emphasis to accelerate early benefits to users by going operational in the '03-'05 timeframe). CAT activities on the other hand, would emphasize more concept exploration (particularly in the area of user collaboration, exploration of using/integrating more TFM control strategies than re-routing, and integration with sector DSTs).

2.3.6. Inter-facility Conflict Probe

The Conflict Probe function projects aircraft positions ahead along their trajectories to determine if conflicts between aircraft can be observed. An extension of conflict probe determines if an aircraft is within a specified region of airspace. Within URET, the look ahead is relatively short (20 minutes) and there is little need to consider the future schedule for activation or de-activation of an SUA. The current status is used in this application. A study of the accuracy of Conflict Probe in determining aircraft conflicts is reported in a paper by William Arthur and Dr. McLaughlin for MITRE CAASD.[25]

The CAT will require the Inter-facility Conflict Probe functions to have a considerably longer look ahead (over an hour) to consider SUA schedules, schedule changes, and weather forecasts.

2.3.7. Human Factors

The effective utilization of CAT requires human factors studies relative to the roles of the controller, traffic manager, AOC, and pilot. The primary concerns are the utility of the information and capability provided by CAT, the utilization of the capability, and determination of effective collaborative solutions.

The work being performed on Dynamic Density (section 2.3.3) includes assessment of controller actions and controller assessment of workload. These two human factors assessments are being applied to the two different approaches to Dynamic Density described previously. An analysis of controller actions, controller assessments of workload, and independent assessments of workload could be applied to both of the identified approaches to Dynamic Density.

The collaborative solution studies that will come out of the CRCT work by MITRE (section 2.3.5) and a work on the computer-human interface requirements similar to that reported in Maria C. Picardi's paper on En Route ATM DST requirements[26] will be needed to ensure full integration of the CAT capability into an operational environment. Additional human factors work is necessary as part of the Distributed Air-Ground program.

2.4. Proposed AATT Research Activities

Based on the proposed operational concept for CAT and the associated functions, there are many areas requiring further study. Below is a partial list. These were deemed the

---

[25] Arthur William C. and Dr. Michael P. McLaughlin, "User Request Evaluation Tool (URET) Interfacility Conflict Probe Performance Assessment," 2d USA/Europe Air Traffic Management R&D Seminar, Orlando, FL, December 1998.

[26] Picardi, Maria C., "En Route ATM Decision Support Tool Computer-Human Interface Requirements Development," 2d USA/Europe Air Traffic Management R&D Seminar, December 1998.

most important, based on the goal of facilitating the development of this concept and its resultant DST. The list is roughly in priority order, with the recommendation to do concept justification (e.g., benefits) and concept feasibility first, followed by functional development. Farther-reaching concept elements and non-critical concept feasibility issues are left to the end. It is fully expected that the priority of these elements could change as early research is completed.

1. Assessment of Problem Magnitudes and Frequency

    An assessment of the magnitude and frequency of the constrained airspace problems must be performed. A general benefits analysis is needed to confirm that further development of the concept is worth the investment, and to focus the R&D on the most beneficial problems to solve for the user and the air traffic service provider.

2. Analysis of Prediction Accuracy and Time Horizons

    As in the development of any DST based on trajectory predictions, the premise that the prediction accuracy of events is sufficient to support the solution time horizons required for strategic solutions must be confirmed.

3. Weather Prediction Assessment

    CAT assumes an accurate ability to predict the formation and dissipation of weather phenomenon. Work in this area is on going. How well the current technology supports the CAT concept must be determined. AATT should collaborate with organizations currently involved with the development of advanced weather systems to ensure that CAT weather requirements are met.

    Areas for further study by the AATT program with respect to weather impacts on en route operations and technologies needed for the CAT DST include:

    - Develop a comprehensive baseline of weather impacts on en route operations based on analyses of climatic meteorological data and ATC traffic data. Determine the type, frequency, location, duration, and complexity of weather events that lead to lost or gained airspace and user requests for routing changes. Determine the impacts of weather on en route operations and assess the consequences for system stakeholders (appropriate metrics must be identified early in this process). Use these analyses to establish requirements for weather information for the CAT DST and to assess the benefits that will be realized if the technology is implemented.
    - Analyze the performance of the weather technologies that will be needed for the CAT DST. This includes the accuracy and uncertainty of meteorological data needed for trajectory synthesis algorithms (e.g., accuracy of RUC upper-air wind and temperature data), and the accuracy of nowcasting and

forecasting tools for predicting the onset and dissipation of disruptive weather events.

- Determine the required level of shared weather awareness between the users (AOC and flight deck) and air traffic service providers.
- Develop the requirements for the functional linkages between ATC and the AOC's with respect to the production and dissemination of weather information and developing consensus on the likely evolution of disruptive weather events.
- Develop representative weather scenarios that can be used in tests and/or simulations of the CAT DST.

4. Functional Development

The CAT concept has been presented at a high level. Work with facility personnel is required to confirm the assessment of desired system functionality and begin the development of these functions.

5. SUA Dynamic Scheduling

The use of provisional planning with gained airspace could be used as an enabler for dynamic negotiation of SUA de-activation. This functionality needs to be further explored. The MAMS and SAMS programs provide distribution of schedules but dynamic schedule modifications may not be so readily distributed, and the infrastructure does not exist to facilitate the dynamic negotiation of SUA status.

Research is necessary on how best to distribute SUA activation and de-activation information to ensure effective and timely access to the information by all potentially concerned parties. The relative benefit of dynamic SUA scheduling also needs attention. The work by Datta[27] is inconclusive and more detailed models for SUA activity is essential. This paper did not, for example, account for the influence of winds on routes that would have resulted in a dramatically different distribution of preferred routings and possible different results.

6. Dynamic Density

Research is necessary to determine the Dynamic Density function necessary to support CAT. The current formulations do no fully account for the loss or gain of airspace prior to re-routing and re-planning. The formulations may need to include an assessment of uncertainty for both weather forecasting and route prediction.

---

[27] Datta, Koushik and Craig Barrington, "Effects of Special Use Airspace on Economic Benefits of Direct Flights," Sverdup Corp., 1996.

7. Display Development

    Development of CAT display/interfaces for traffic flow managers.

8. Automated Rerouting Algorithm Development

    Rerouting is the cornerstone of solutions in the CAT concept. Manual rerouting can be effective, but automated routing advisories are required for high workload situations (like weather lost airspace problems) to ensure complete and accurate consideration of all alternatives. The field of automated routing algorithms should be evaluated and algorithms adopted, extended or created.

9. Gained Airspace Algorithm Development

    Algorithms for the identification of aircraft flights that will benefit from gained airspace need to be developed. There a research should include the investigation of best interaction with the users for this identification. Options include sending the identified aircraft to the users (i.e., "pushing" the data) or sending the identified airspace gain to the users and receiving pack from them the list of effected aircraft (i.e., "pulling" the data).

10. Metrics Development

    Metrics are needed to evaluate the benefits gained in rerouting solutions and in the identification of aircraft for gained airspace solutions. These metrics will form the basis of CAT functionality to provide automated problem identification and resolution.

11. User Collaboration Development

    Many of the solutions presented have the ability to benefit from user collaboration. This is a prime area for explorations since user flexibility is a pacing item in future FAA systems.

12. Integration with Sector DSTs

    The CAT concept is primarily focused on the development of a TMU DST, but there is a perceived need for integration with Transition and Non-Transition sector tools. This part of the CAT concept must be further developed.

13. Automated Event Data Collection

    Identifying many of the events, including SUA activation/de-activation and user requests, could be improved with automated collection of data from sources outside the TMU. An assessment of the availability of this data is required. The FAA has several activities in this area and further assessment may (or may not) point to gaps that NASA should fill as part of the NAS Modeling and Simulation efforts with AATT.

14. Assessment of Multi-Facility Issues

With the correct prediction accuracy, the solutions described in the CAT concept could easily expand beyond a single ARTCC boundary. The impact of inter-facility procedures and data flow needs to be evaluated. A gap is not expected. The CRCT multi-facility collaboration and communications work by MITRE will continue to be an important.

3. Conclusions

The goal of this task order was to define the Constrained Airspace problems and to develop a concept for their solutions. In the developed concept, it was further desired to identify areas for further research for AATT. This task order produced such a problem definition, a solution concept and areas for research. Beyond that, the solution developed is feasible, integrates well with NASA's current and future research plans, and has the potential to achieve significant benefits for airspace users and service providers. The areas of research identified are the logical next steps for continuing to develop the system concept and identifying the actual benefits to be gained.

A. References

"An Evaluation of Air Traffic Control Complexity," NASA-ARC Contract # NAS2-14284, Wyndemere Incorporated, October 1996.

"Code of Federal Regulations and Aeronautical Information Manual Aviation," 1998 Aviation Supplies & Academics, Inc. (ASA), Newcastle, WA 1998.

Aviation Week & Space Technology, "Turbulence Special Report," July 27,1998.

Bayles, Scott, C. Branscome, R. Cormier, E. Hisel and D. Rowe, "1997 Field Visits Air Traffic Service Plan," The MITRE Corporation-Center for Advanced Aviation System Development, McLean, VA, June 1997.

Brinton, Chris, Bill Pawlak, Ken Lancaster, Kim Crouch and David Rothenberg, "Air Traffic Control Complexity Research and Application" (Presentation), Wyndemere Incorporated, William J. Hughts Technical Center, August 29, 1997.

Boeing Commercial Airplane Group, "Flight Management System-Air Traffic Management Next Generation (FANG) Operational Concept," Federal Aviation Administration, February 1996.

Carlson, Laurel S. and Lowell R. Rhodes, "Operational Concept for Traffic Management Collaborative Routing Coordination Tools," The MITRE Corporation-Center for Advanced Aviation System Development, McLean, VA, July 1998.

Cormier, Robert H., "National Airspace System Performance: Results of the 1997 Pilot Opinion Survey," The MITRE Corporation-Center for Advanced Aviation System Development, McLean, VA, March 1998.

Data Link Benefits Study Team, "User Benefits of Two-way Datalink ATC Communications: Aircraft Delay and Flight Efficiency in Congested En Route Airspace," Federal Aviation Administration, February 1995.

Datta, Koushik and Craig Barrington, "Effects of Special Use Airspace on Economic Benefits of Direct Flights," Sverdup Corp., 1996.

Department of Defense, "GATO/MC2 Concept of Operations," Version 1.0, August 21,1997.

Department of Defense, "Letter of Agreement between Albuquerque Center: 49th Fighter Wing: Detachment 1, 46th Test Group, and White Sands Missile Range," September 1, 1998.

DiMeo, Karen, "Dynamic Density: Joint Study Plan," ACT-540, Federal Aviation Administration Technical Center, August 27, 1999.

DiMeo, Karen and Parimal Kopardekar, “Dynamic Density: Metric Variables” (Presentation), Federal Aviation Administration Technical Center, March 15, 1999.

Dropco, Kenneth M., “The Navy’s Global Weather Satellite Imagery Collection And Dissemination System," Naval Oceanographic Office, Stennis Space Center, MS 1999.

Federal Aviation Administration Office of System Architecture and Analysis, “National Airspace System Architecture 3.0," Federal Aviation Administration, December 1997.

Federal Aviation Administration, “A Concept of Operations for the National Airspace System in 2005 (revision 1.3)," June 27, 1997

Federal Aviation Administration, “A Concept of Operations for the National Airspace System in 2005-Operational Tasks & Scenarios (Draft)," February 5, 1998.

Federal Aviation Administration, “Air Traffic Control Handbook ATP-7110.65," February 1998.

Federal Aviation Administration, “Collaborative Decision-Making in Aviation Transportation," July 1997.

Flight Library Series (CD-ROM), ASA/Summit Aviation Inc., 1998.

Green, Steve M., “Enabling User Preferences Through Data Exchange," National Aeronautics and Space Administration.

Green, Steve, Dr. Tsuyoshi Goka, and David H. Williams, “Enabling User Preferences Through Data Exchange," AIAA Guidance, Navigation, and Control Conference Submittal, New Orleans, LA August 12, 1997.

Green, Steve and Rhonda Slattery, “Conflict-Free Trajectory Planning for Air Traffic Control Automation," National Aeronautics and Space Administration, January 1994.

Haraldsdottir, Aslaug, Monica S. Alcabin, Alivin H. Burgemeister, Charles G. Lindsey, Nigel J. Makins, Robert W. Schwab, Arek Shakarian, William D. Shontz, Marissa K Singleton, Paul A van Tulder, and Anthony Warren, “Air Traffic Management Concept Baseline Definition," NEXTOR Report #RR-97-3, Boeing Commercial Airplane Group, October 31, 1997.

Heimerman, Kathryn, "Proceedings of the First FAA Dynamic Density / Air Traffic Control Complexity Technology Exchange Meeting," MT98W0000015, MITRE Corporation, McLean, VA, November 1997.

Hoffman, Robert, William Hall, Michael Ball, Amedeo Odoni, and Michael Wambsganss Collaborative Decision Making in Air Traffic Flow Management," January 5, 1999.

Hollenberg, Joseph M., Nora Lawson, Kenneth H Thompson, and Karen J. Viets, “Proposed En Route National Airspace System (NAS) Midterm Operational Concepts (Revision 2)," The MITRE Corporation-Center for Advanced Aviation System Development, McLean, VA, September 1998.

Hung, Josh, “Flight Object Model Work Group Status Report” (Presentation), Federal Aviation Administration, January 28, 1999.

Kassube, Bradley V., “The Military Aircrew Information Service (MAIS) –Helping Aircrews Navigate The Maze Of Weather Information," Headquarters Airforce Weather Agency, Offutt Air Force Base, NE; and MA 1999.

Kleckner, David, “Providing Aviation Weather Support Through The Internet," United Airlines, Chicago, IL, 1999.

Kuchar, James K and Kashif A. Khan, “Integration of Reusable Launch Vehicles into Air Traffic Management (Phase1)," NEXTOR Research Report RR-97-7, Cambridge, MA 1997.

Kuchar, James K and Kashif A. Khan, “Integration of Reusable Launch Vehicles into Air Traffic Management (Phase2)," NEXTOR Research Report RR-98-13, Cambridge, MA 1998.

Laudeman, Irene, Connie Brasil and Robert Branstrom, “Air Traffic Control in Restructured Airspace: A Study in Tactical Decision Making” (Presentation), NASA Ames Research Center, San Jose State University, and University of California-Berkeley.

Lindsey, Charles G., “Aviation Weather Study” (Final Report), NWRA-CR-98-R185, Boeing Commercial Airplane Group, Seattle, WA, December 31, 1998

McNally, B.D. “Technologies for User Preferred Routing," 15th Digital Avionics System Conference: Atlanta, GA Oct 27-31,1996.

Mineta, Norman Y., “Avoiding Aviation Gridlock & Reducing the Accident Rate: A Consensus for Change” National Civil Aviation Review Commission, December 1997.

National Aeronautics and Space Administration, “Advanced Air Transportation Technology En Route Results Summary," May 1998.

National Aeronautics and Space Administration, “The Effects of Update Rate on Tracking Accuracy,” November 1997.

National Oceanic and Atmospheric Association, “IFR En Route High Altitude- U.S. Charts (H1, H2, H3, H4, H5, H6)," United States Government Flight Information Publication, August 13, 1998.

NEXTOR, “Traffic Management for Collaborative Decision Making (CDM), 1997-Present," Sponsor AUA-500, Michael Ball UMD, Amedio Odoni MIT, Michael Wambsganss, Metron Industry, 1996.

Pawlak, William S., Anita Bowles, Vikas Goel, and Christopher Brinton, “Initial Evaluation of Dynamic Resectorization and Route Coordination (DIRECT) System Concept," Wyndemere Incorporated, August 27, 1997.

Reininger, Brian , “Technology and Procedures Report," NAS2-14279, Prepared for NASA Ames Research Center by Honeywell, American Airlines, Crown Communications, Lockheed-Martin, McDonnell Douglas, 1996.

Remington, Roger, “Assessing Sector Controller Situation Awareness Under Simulated Free Flight Conditions," (Milestones 5.0.2&5.0.3) Cognition Group AATT Research, NASA-ARC, EnRoute Systems & Operations.

Rock, Dennis and Edward J. Sullivan, “Negotiation Automation for Special Use Airspace," The Boeing Company and ANSER Inc., 1999.

Rodgers, Mark, William Colligan, and Donald Embt, “An Analysis of the Effects of Data link Equipment Rates and Facility Differences on En Route Voice Communications," AIAA-98-4289, CSSI, Inc., 1998.

RTCA, Inc., “Operational Concepts and Information Elements Required to Improve Air Traffic Management (ATM)-Aeronautical Operational Control (AOC) Ground-Ground Information Exchange to Facilitate Collaborative Decision-Making," DO-241, October 6, 1997.

RTCA, Inc., “Operations Concepts for Data Link Applications of Flight Information Services,” DO-232, March 13, 1996.

RTCA, Inc., “Final Report of RTCA Task Force 3 Free Flight Implementation," October 26, 1995.

Select Committee on Free Flight Implementation, “A Joint Government/Industry Operational Concept for the Evolution of Free Flight," RTCA Inc., August 1997.

Sherretz, Lynn A., G. Thomas and T. Mahony, “Overview of the Aviation Digital Data Service," NOAA/FSL, Boulder, CO 1999.

Smith, Phillip, Charles Billings, David Woods, Elaine McCoy, Nadine Sarter, Rebecca Denning, and Sidney Dekker, “Can Automation Enable a Cooperative Future ATM System?," May 1,1997.

Smith, Phillip, David Woods, C. Elaine McCoy, Charles Billings, Nadine Sarter, Rebecca Denning, and Sydney Dekker, “Using Forecasts of Future Incidents to Evaluate Future ATM System Designs," ATC Quarterly Submittal, November 1997.

Smith, Phillip, Elaine McCoy, and Charles Layton “Brittleness in the Design of Cooperative Problem Solving Systems: The Effects on User Performance," May 1997.

Smith, Phillip, Elaine McCoy, Judith Orasanu, Charles Billings, Amy Van Horn, and Rebecca Denning, “Interactions of Airline Operations Control Centers with the Air Traffic Management System” Ohio State University, Ohio University, and NASA Ames Research Center, Presented at the AIAA Guidance and Control Conference, July 29-31, 1996.

Smith, Phillip, Elaine McCoy, Judith Orasanu, Charles Billings, Rebecca Denning, Michelle Rodvold, Theresa Gee, and Amy Van Horn, “Control By Permission: A Case Study Of Cooperative Problem Solving In The Interactions Of Airline Dispatchers With The ATCSCC," September 1996.

Smith, Phillip, Elaine McCoy, Judith Orasanu, Rebecca Denning, Amy Van Horn, and Charles Billings, “Cooperative Problem Solving In The Interactions Of Airline Operation Control Centers With The National Aviation System," Ohio State University, September 1995.

Smith, Phillip, Elaine McCoy, Judith Orasanu, Rebecca Denning, Amy Van Horn, and Charles Billings, “Human Factors Issues in the Design of a More Flexible ATM Environment: Knowledge Elicitation Based on the Expanded National Route Program," Ohio State University, January 31,1997.

Smith, Phillip, Elaine McCoy, Judith Orasanu, Rebecca Denning, Charles Billings, Thomas Owlsey, Evans Boeve, Rob Bullington, and Elizabeth France, “An Empirical Study of the Impact of the Expanded National Route Program on Flight Planning and Performance," Ohio State University, December 1996.

Smith, Phillip, Karol Kerns, C. Elaine McCoy, and Judith Orasanu, “Ergonomic Issues in Air Traffic Management," The MITRE Corporation-Center for Advanced Aviation System Development, Ohio State University, Ohio University, NASA-ARC, 1997.

Smith, Phillip, C. Elaine McCoy, Judith Orasanu, Charles Billings, Amy Van Horn, Rebecca Denning, Michelle Rodvold, and Theresa Gee. “Airline Dispatch and ATCSCC: A Cooperative Problem-Solving Success Story with a Future," 1995 Proceedings of the Aviation Psychology Symposium, Ohio State University, 1995.

Sridhar, Banavar, Kapil S. Sheth and Shon Grabbe, “Airspace Complexity and its Application in Air Traffic Management," MS 210-10, NASA Ames Research Center, Moffett Field, CA, December 1998.

Suchkov, Alexander, Donald Embt, and William Colligan, “Dynamic Density Study," CSSI, Inc., December 1997.

Swenson, Harry N., “Design and Operational Evaluation of the Traffic Management Advisor at the Fort Worth Air Route Traffic Control Center," National Aeronautics and Space Administration, June 17-19, 1997.

Toma, Nancy, Dr. Laurel Carlson, Dr. Ellen Cherniavsky, Graham Glover, John S. Ludwick, Lowell Rhodes, Dr. Duane Small, and Mary Yee. “Midterm Operational Concept for

Collaborative Traffic Management-Revision 1 (draft)," The MITRE Corporation-Center for Advanced Aviation System Development, McLean, VA, November 1997.

Vivona, R.A., "A System Concept for Facilitating User Preferences in En Route Airspace," National Aeronautics and Space Administration, November 1996.

Volpe Research Center, "FAA Enhanced Traffic Management System Functional Description," U.S. Department of Transportation, Cambridge, MA, August 1988.

Volpe Research Center, "Volpe Center Presentation to NASA Ames Research Center on Potential Areas of Support to the AATT Program," U.S. Department of Transportation, Cambridge, MA, April 10, 1997.

B. Contact Summary

The contacts listed cover a broad range of technology and expertise. Most of the contacts were with Air Traffic Control researchers; however, the list includes Air Traffic Controllers (some retired, some active), dispatchers and AOC personnel, and pilots. Mr. Craig Hodgdon, one of the authors, is a commercially rated pilot and was a dispatcher for SkyWest (Delta Airlines connection).

Chris Brinton
Metron
Reston, VA
(703) 787-8700
Subject: Dynamic Re-Sectorization work

Parimal Kopardekar, Ph.D.
Project Manager-System Resources Corporation
Mays Landing, NJ
(609) 625-5669
Subject: Current Dynamic Density studies being conducted.

Jeremey Banford
Wyndemere Incorporated
Boulder, CO
(303) 444-8123
Subject: Dynamic Re-Sectorization Final Report funded through NASA Ames.

Edward Delacey
Quality Control Specialist
Federal Aviation Administration-New England Regional Headquarters
Burlington, MA
(781) 238-7535
Subject: FAA OPSNET and NAPERS Delay Reporting System

Vicki Chatel
Quality Control Specialist
Federal Aviation Administration-Air Traffic Control System Command Center
Washington, D.C.
(703) 904-4473
Subject: FAA Delay data per domain (En Route)

Randy McGuire
rmcguire@mitre.org
MITRE Corporation CASSD-(Center for Advanced Aviation Systems Development)
Virginia
(703) 883-3680
Subject: MITRE R&D in the Enroute Domain

Ed Carrigan
MITRE Corporation CASSD-(Center for Advanced Aviation Systems Development)
Virginia
(703) 883-7133
Subject: User Request Evaluation Tool (URET) & Initial Conflict Probe

Gene Wilhelm
MITRE Corporation CASSD-(Center for Advanced Aviation Systems Development)
Virginia
(703) 883-6516
Subject: En Route Operational Concepts & Collaborative Routing and Coordination Tool (CRCT)

John Pyburn
MITRE Corporation CASSD-(Center for Advanced Aviation Systems Development)
Virginia
(703) 883-5546
Subject: Mid-Term Collaborative Routing Concept of Operations, Collaborative Routing Coordination Tool (CRCT), and SUA Information

Mr. H. Shahidi
MITRE Corporation CASSD-(Center for Advanced Aviation Systems Development)
Virginia
(703) 883-6410
Subject: Near Term Procedures- Miles-In-Trail Restrictions

Mr. Wengert
Plans and Procedures Specialist
Federal Aviation Administration
Albuquerque Air Route Traffic Control Center (ARTCC-ZAB)
New Mexico
(505) 856-4530
Subject: SUA Coordination Issues between ZAB and WSMR's Cherokee Control

Judge Coles
Plans and Procedures Specialist
Federal Aviation Administration
Boston Center-(ZBW)
(603) 879-6655
Subject: TMU/AOC Collaboration Procedures

Edward Madigan
System Resources Corporation
Washington, DC
(202) 488-9740 ext. 113

Subject: OASIS program with Harris Corporation

Dennis Rock
Boeing Commercial Airplane Group
AIAA Technical Fellow
Philadelphia, PA
(610) 591-3848
Subject: Boeing SUA Management Report

Edward J. Sullivan
FAA/Air Space Analyst
ANSER, Inc.
Arlington, VA
(703) 416-2000
Subject: Boeing SUA Management Report

Koshik Datta
Systems Engineer
Sverdup Corporation
NASA Ames Research Center
Subject: Economic benefits of SUA usage for direct flights report

Bruce Burton & Arlow Cambell
WSI, Corporation (A Litton Company)
Bellerica, MA
(978) 670-5000
Subject: WSI's Pilotbrief commercial weather products system and capabilities.

Professor Roger Bacchieri
Air Traffic Control Program
Daniel Webster College
Nashua, NH
(603) 577-6452
Subject: FAA SIMMOD Program & Current Academia En Route Research

Professor Tom Teller
Air Traffic Control Program
Daniel Webster College
Nashua, NH
(603) 577-6427
Subject: FAA SIMMOD Program & Current Academia En Route Research

Professor Gary Bartelson
UND Aerospace-Air Traffic Management Program
University of North Dakota
Grand Forks, ND

(701) 777-2791
Subject: Current Academia En Route Research

Charles G. Lindsey
NorthWest Research Associates, Inc.
Bellevue, WA
(425) 644-9660
Subject: The *Aviation Weather Study* and current state of the art weather technology research.

Darrell L. Crapps
Corporate Counsel
Dimensions International, Inc.
Alexandria, VA
(703) 998-0098
Subject: Copyright permission to reproduce graphic images from DI's Flight Explorer internet-based Aircraft Situational Display (ASD).

Grace Marie Potorti
Rural Alliance for Military Accountability
Nevada
(702) 677-7001
Subject: Special Use Airspace Management topics and DoD studies

Harry Ulrich
Director of Marketing FlightWinds commercial products
Lockheed Martin Corporation
Management & Data Systems
Philadelphia, PA
(610)354-3310
Subject: FlightWinds product and existing research being conducted.

Banavar Sridhar, Ph. D.
NASA Ames Research Center
Moffett Field, CA
(650) 604-5450
Subject: Dynamic Density and airspace complexity in relation to Air Traffic Management.

Jack Sner
Contract Lockheed Martin Employee
Copethunder Program
Eielson AFB
Fairbanks, Alaska
(800) 758-8723
Subject: Special Use Airspace Information Service in use for the Eielson Air Force Base and associated Special Use Airspace.

Reginald Arsenault
Aviation Specialist
Jeppesen Sanders
Englewood, Colorado USA
(303)-799-9090
Subject: Jeppesen's commercial flight planning and aircraft fleet coordination services.

C. Letter of Agreement

The Letter of Agreement between Albuquerque ARTCC and the 49th Fighter Wing Detachment 1,46th TEST GROUP; and WHITE SANDS MISSILE RANGE was provided by the assistance of Mr. Wengert from ZAB. This document outlines the policies and procedures set for the handling of the Special Use Airspace associated with the White Sands Missile Range. A copy of this document is only included with the printed version of this report and will not appear here in an electronic form.

D. Decision Support Tools And Concepts Of Operation

D.1 Introduction

This appendix contains the results of an examination of the FAA Air Traffic Services and NASA AATT view of the future decision support environment; the SRC problem definitions and approach are consistent with these visions.

The FAA future vision is contained in two documents. The "ATS Concept of Operation for the National Airspace System in 2005 - Narrative" (Narrative) is a 28 page document which includes two sections directly relevant to Constrained En Route. Section 5 of the Narrative is "En Route/Cruse Operations and Services" and Section 7 is "NAS Management." The second document is the "ATS Concept of Operation for the National Airspace System in 2005 - operational Tasks & Scenarios" (Addendum) which is a 160 page document consisting of operational task threads and scenarios which build upon the Narrative. SRC recently completed a study of these two documents and their impact on NAS in the report "Level I and II Concept of Operations Analysis." The accumulated results in this section were developed using the Level I (Narrative) and Level II (primarily the Addendum) analysis to identify all references relevant to decision support tools related to the en route environment.

The NASA AATT OPSCON was developed for NASA by combining the Narrative and a corresponding RTCA document. This AATT concept of operations document was developed to meet AATT Milestone 1.0.0. Because the Narrative is included in this AATT OPSCON document, the results identified in this appendix apply equally to the AATT future vision.

D.2 Analysis Description And The Level I and II CONOPS Analysis

This material consists of extracts from the Narrative and the Addendum. The text in a highlighted box is from the Narrative and is always preceded by a number like "5.10." The number is the specific reference to a one of 325 "CONOPS entries" that are the Level I CONOPS extracted directly from the Narrative. The referenced SRC report has a full list of the CONOPS entries and points out their location in the Narrative. Following each highlighted Level I CONOPS entry are text entries from either the Narrative or the Addendum. The Addendum material is preceded by "(II)" which identifies he material as a Level II CONOPS entry. Again, the referenced SRC document provides a complete summary of this material and points out the location of the Level II material in the Addendum. When the text is preceded by a number in parentheses like "(4.49)" the material is actually a Level I CONOPS entry which is relevant to the higher level highlighted text.

This analysis is subdivided into System Effectiveness, Collaboration Between Users and Service Providers, NAS-Wide Status Information, Service Provider – Decision Support, Traffic Management – Decision Support, Controller Workload, Advisories to Controllers, Separation Assurance, Trajectory Prediction, and User-Preferred Trajectories.

D.3 Analysis Results

System Effectiveness

5.10 Decision support systems such as the conflict probe assist the service provider in developing safe and effective traffic solutions.

(II) Automation provides more assistance than today's system in task performance and decision-making. But while these new system functions change controllers' thought processes and manual tasking, controllers continue their role as fully-engaged decision-makers in the organization and separation of traffic.

(II) New system functions include task-performance aids that assist in the execution of manual tasks, and decision support systems that augment the controller's cognitive processes. Together, these aids and DSSs generate a greater increase in traffic capacity than either type of assistance produces individually. As a result, controllers are able to handle more traffic without incurring additional workload,

(II) Decision-Making. While task-performance aids increase the number of decision controllers can implement, DSSs increase the number of decisions they can make. Today, controllers mentally model all flights under their control. This mental analysis is made more difficult by increased traffic volume and complexity in 2005. Therefore, DSSs indicate flights that require controllers' fullest attention, and, by the absence of such alerts, indicate the flights that do not require as detailed attention.

(II) Meet Procedural Requirements While automation provides assistance in the performance of these tasks, controllers are responsible for ensuring the implementation of procedurally required tasks such as handoffs, pointouts, communications transfers, letter-of-agreement (LOA) speed and altitude restrictions, etc.

(II) Implement TM Initiatives - Traffic managers and TM DSSs detect demand/capacity imbalances and develop TM Initiatives to address them. These Initiatives consist of NAS configuration changes to optimize capacity, and/or traffic restrictions to modulate demand. Controllers implement NAS Configuration changes, and execute flight-specific control instructions as required to modulate demand.

(II) With tasktime per airplane greatly reduced through the use of task performance aids, controllers have time to handle more traffic than they can conveniently analyze. DSSs therefore assist controllers in their analysis by detecting problems and providing resolutions in the two general areas of traffic planning and conflict detection.

(II) Traffic Planning   Traffic Management (TM) DSSs monitor demand on all relevant ATC resources such as airports, runways, routes, and sectors. Each of these resources has a specific capacity that is defined in real time based on environmental and traffic factors. When demand is predicted to exceed the capacity of a resource, TM DSSs determine demand modulation requirements based on criteria specified by the traffic manager. The resulting TM Initiatives are implemented by controllers based on system- generated control-action advisories.

(II) En Route and Arrival Planning. The system automatically determines if predicted demand exceeds the capacities of sectors, routes, and arrival airports. Excess demand is modulated using 1) airborne demand modulation techniques such as metering, miles-in-trail restrictions, or speed restrictions, or 2) departure-point demand modulation using approval requests, ground stops, ground delays, etc. When the capacity of a resource is exceeded, the system provides controllers with the control- action advisories required to implement the demand modulation technique specified by TM. These advisories are usually presented to the controller in the form of input selection options.

(II) Conflict Detection ...... the system provides automatic conflict detection at all sectors and surface control positions. It also provides on-request trial-planning at selected sectors and positions. The automatic probe alerts controllers to conflicts based on the current trajectories of the interacting flights. When flights are not in conflict on their current trajectories, but require action to meet operational objectives such as sequencing and spacing, controllers may use the trial planning function to test mentally- generated control-action options in order to avoid putting the flights into conflict. The system provides resolution options for any conflict, whether detected automatically or through trial planning. These detection and resolution capabilities draw controllers' attention to critical traffic interactions, while allowing them safely to reduce the attention paid to the balance of the traffic that is considered problem-free by the system.

(II) Automatic conflict detection and resolution allows controllers to work traffic of higher volume and greater complexity than is feasible under the current system. Using these tools, a controller may direct a flight into a complex situation and then turn to other tasks with confidence that the lack of a conflict warning indicates that in-depth analysis of the situation is not required.

(II) In 2005, problems are detected in the time it takes to observe a conflict warning, resolutions are automatically provided, and the results of plots and calculations previously performed manually are available upon request.

(II) 1.4 MAKE CONTROL DECISIONS & IDENTIFY REQUIRED TASKING As the final stage of maintaining situation awareness, the ECON (En route control) controller makes control decisions and determines the tasking required to implement them. To assist in the controller's decision making and task identification, the system provides 1) automatic and on-request conflict detection and resolution,   2) task prompts for time-constrained tasking, 3) TM information and control advisories, 4) user-preferred trajectory information, and 5) flight-specific delay data. Based on these aids and information, the controller makes decisions and identifies tasks that will assure air safety, meet procedural requirements and TM Initiatives, and maximize conformance to user-preferred trajectories. The following tasks describe this decision making and task identification process in the ECON environment.

(II) 1.4.1 ECON controllers assure air safety by detecting potential conflicts with aircraft, SUAs, terrain, and weather. Each flight is automatically checked for conflicts on its current trajectory. Upon controller request, the system also performs `trial plan' checking for conflicts on alternative trajectories. Automatic and trial plan conflict detection is based on 1) aircraft equipage, 2) trajectory information, 3) aircraft performance as a function of weight, atmospheric conditions, and user operating characteristics, 4) user-preferences, 5) pilot-intent of self-separating flights, and 5) geographic information. Aircraft equipage is determined from the flight profile.

(II) 1.4.1.c Task Objective: Detect conflicts on alternative trajectories. Background: The previous Tasks discussed the automatic detection of conflicts based on the currently-cleared trajectories of the traffic. Before changing a flight's trajectory, the controller must ensure not only that the revised trajectory is free of conflicts, but that the transition to that trajectory is also conflict free. The system therefore provides a 'trial plan' conflict probe for testing alternative trajectories. These trajectories generally arise from a pilot request, or from a resolution the controller mentally generates in response to an automatically detected conflict. On-request trial planning is provided at selected sectors. Simple inputs and succinct system outputs make trial planning feasible at a single-controller sector under high traffic volume and complexity. Automatic trial planning is performed at selected sectors based on user-supplied altitude profile information, per Task 1.4.4, below.

(II) 1.4.3 For time-based solutions, TM DSSs develop a Demand Modulation Schedule (DMS) that assesses the times at which individual flights must depart from or arrive at specified resources.

(II) 1.4.3 TM Initiative Implementation. To implement a time-based solution, the traffic manager 'activates' the DMS, and appropriate control-action advisories are automatically output at the relevant sectors and/or SCON control positions. Upon the traffic manager's activation of a trajectory-based solution, the system distributes the necessary route, altitude, and runway information to the appropriate control positions as preplanned TM directives, which are implemented by the controller(s) as soon as feasible. Upon TM activation of a combined time- and trajectory-based solution, trajectory information is distributed to sectors as preplanned TM directives (which are implemented by the controller as soon as feasible), and DMS-based control-action advisories are output on the data blocks and FIPs at relevant control positions.

(II) 1.4.4 At the appropriate times, the requested climb is automatically trial-planned and then distributed to the relevant sector as a de-conflicted `next available altitude' advisory. While uninterrupted climb remains the goal, interim climb altitudes based on the trial plan are distributed to the controller as required. Trial planning then continues automatically, providing the controller with `next available altitude' data as the flight progresses, until the flights latest altitude request is met.

(II) 1.4.4 Upon a flight's egress from a Free Flight route, controllers continue to accommodate an optimal descent profile. Optimum tops-of-descent are calculated by NAS based on aircraft performance and weight, optimum descent speed, length of route to the runway (based on traffic considerations), and winds aloft. These calculations are used for automatic conflict probes and (at sectors equipped with the capability) on- request trial planning. These tools increase the opportunities to eliminate speed and altitude restrictions on a per flight basis. At the appropriate time, the descent is automatically trial-planned and then distributed to the relevant sector as a conflict-free descent advisory. While uninterrupted descent remains the goal, interim descent altitudes based on the trial plan are distributed to the controller as required. Trial planning then continues automatically, providing the controller with `next available altitude' data as the flight progresses.

(II) 1.4.5 The system provides `cumulative delay' information that quantifies the total delay an aircraft absorbs throughout its flight. TM DSSs use this information as one variable in the determination of traffic flow sequences.

(II) 2.1   DSSs identify problems involving the flight, and allow them to be resolved through early coordination with the upstream controller.

(II) 3.1.2 Most clearances require the input of a NAS message to reflect the action in automation. Many of these inputs can be entered using automatically provided input selection options on the flight's data block and/or FIP. These input options are based on information provided by the DMS and other DSSs.

5.11 decision support systems allow more aircraft to operate on routes according to the most favorable winds … with additional available altitudes.

Collaboration Between Users and Service Providers

1.30 The system allows increased collaboration between users and service providers for resolving strategic problems.
5.46 Decision support tools also help service providers to collaborate with users when SUA restrictions are later removed or changed.
7.33 Increased collaboration among local facilities, the ATCSCC and NAS users is augmented by decision support systems that enable a shared view of traffic and weather with all parties.

5.22 Times remain when projected airspace demand is at or near capacity. In these instances, after collaboration between the users and traffic management, temporary routes and associated transition points are identified using the global location grid.

(II) 1.2.2 Monitor non-flight-specific information. Task Objective — Plan general traffic-handling requirements in accordance with predicted demand levels. Background (Sector) — Controllers receive several types of non-flight-specific information that allows them to assess traffic demand. The system measures and predicts the traffic density at all sectors. Dynamic measurements and near-term predictions of each sector's traffic density are available at that sector. Other examples of non-flight-specific outputs include DSS schedule information, and load graphs that indicate demand at selected fixes (e.g., meter fixes, etc.).

5.43 The activation of an SUA results in the reevaluation of all flight trajectories in the NAS-wide information system, to determine which flights will penetrate the SUA.

5.45 When flights are in close proximity to the newly activated SUA, the service provider uses aircraft-to-aircraft conflict detection tools as aids to prevent them from entering the restricted airspace. … earlier intervention and the closer-proximity resolution

5.46 Decision support tools also help service providers to collaborate with users when SUA restrictions are later removed or changed.

7.1 NAS infrastructure management and air traffic management are creating an environment of user flexibility, collaborative partnership, and information sharing among themselves and with their users.

(II) 2.2.1 In operation, the system analyzes the prevailing traffic demand, and provides the traffic manager with decision support for determining the points at which arrivals must join their terminal routing, and at which departures may exit their terminal routing.

7.27 Information collection and exchange, automated decision support, and remote monitoring and control systems are effectively integrated.

7.6 manage and implement broad scope traffic restrictions, facilitate coordination among other domestic/international service providers, and interact with AOC facilities and other NAS user organizations.

(II) To begin the TM Initiative planning process, the system provides automatic notifications of demand/capacity imbalances, and at the same time generates a TM Initiative Planner. The Planner provides current and predictive traffic information, and enables traffic managers to analyze traffic dynamics under alternative conditions. In addition, the Planner is used for coordination between STMs, ADTMs, ETMs, NTMs, and ATC supervisors, as well as for collaborative decision making (CDM) with users .

(II) 1.3.3 In the planning process described in Task 2.0, traffic managers collaborate with users and coordinate with other traffic managers to determine the actions that will meet the operational objectives of ATC, TM, and users. Based on the decisions that result from this coordination/CDM process, TM DSSs compare demand and capacity at critical resources.

(II) 2.1 The system provides automatic notifications of imbalances and SUA/weather penetrations. The system also automatically generates a TM Initiative Planner that provides the capabilities required to resolve the condition that generated the alert. These capabilities enable traffic managers to access current, predictive, and historical traffic information, analyze traffic dynamics under alternative conditions, coordinate with other service providers, and facilitate collaborative decision making with users .

7.7 Continuous evaluation of traffic management initiatives, to determine their effectiveness and their impact on users.

(II) 3.1 CONDUCT A TM INITIATIVE BRIEFING ask 2.0 above discussed the process of developing a TM Initiative. The traffic managers responsible for conducting this development process are procedurally defined so as to have the relevant decision making done at the lowest possible level. To the extent possible, these roles and responsibilities are reflected in automation in the form of system generated distribution lists, which define the initial dissemination of system-generated notifications and TM Initiative Planners. The traffic managers with primary decision making responsibility may tailor this list through ad-hoc additions and deletions, as required.

(II) 3.2.2 TM Initiative Revision & Termination. If the various metrics indicate the need for a revision to the TM Initiative, coordination/CDM participants may use Planner's fast-time analysis capability to evaluate and select alternative responses. With the concurrence of all coordination/CDM participants, demand modulation is terminated when the predicted unrestricted demand falls consistently below the capacity of the impacted resource. Some Initiatives are terminated by specifying the last flight to be subjected to the traffic restriction. When the demand/capacity imbalance has abated and demand modulation is terminated, the Planner is suppressed from the traffic managers' displays, and DSS control information ceases to be routed to ATC control positions.

7.33 Increased collaboration among local facilities, the ATCSCC and NAS users is augmented by decision support systems that enable a shared view of traffic and weather with all parties.

7.34 "what-if" tools for both the service provider and the NAS user allow proposed strategies to be evaluated.

7.65 User flexibility is significantly expanded by advance information about demand and capacity … revising their plans in a timely manner.

(II)The NAS serves heavier traffic while also increasing safety. New tools enable users to determine the most advantageous flight trajectories, and allow controllers to accommodate them. Since increased user demand and system flexibility result in greater traffic complexity, decision support systems (DSSs) assist controllers and pilots in preventing conflicts with airspace, weather, terrain, and other aircraft.

(II)TM Planning Processes The most typical demand modulation techniques are either time-based or trajectory-based. Time-based solutions implement the DMS by placing aircraft at specified locations at specified times. This may be achieved through time-based metering, miles-in-trail restrictions, speed restrictions, and/or ground delays. Trajectory-based solutions direct flights away from an impacted resource through the use of reroutes, altitude changes, or runway reassignments. For a combined solution, traffic managers may specify the amount of delay that is acceptable for a DMS-based solution. The Planner then selects flights for removal from the traffic population, proposes revised trajectories for them, and updates the DMS accordingly.

NAS-Wide Status Information

1.37 Users and service providers collaborate in this prioritization and scheduling, utilizing decision support tools that provide information regarding the coverage and status of NAS infrastructure components.
1.38 There is increasingly accurate weather data available to the service provider and user.

4.49 service providers utilize the decision support systems to monitor traffic flows, NAS performance, and weather.

5.28 Weather data are distributed to decision support systems for processing and presentation to service providers, resulting in a more accurate and common awareness of meteorological conditions.

1.39 Enhanced steps for avoiding convective weather are made as weather tools are improved and integrated into the decision support tools.

1.40 There are improved methods and tools to measure NAS performance and to identify user requirements, including the daily archiving of the NAS wide information system. These improvements are geared toward providing the information in a meaningful and readily accessible form.

7.37 decision support systems that evaluate NAS performance in real-time enable the service provider to be more responsive and to develop more effective traffic management strategies.

2.9 The flight profile is a part of a larger data set called the flight object. This data set is available throughout the duration of the flight, both to the user, and to service providers across the NAS.

(II) The overall flight object data set includes flight profile information, track data, task prompts, coordination information, and conflict warnings and descriptions. It also includes system-generated input selection options for procedural tasks, conflict resolution options, controller preplanning, and DSS control action advisories.

5.55 The service provider is given demand forecasts throughout the day via the continually updated NAS-wide information system.

(II) Demand Information — Controllers receive several types of non-flight-specific demand information that enables them to assess current and upcoming traffic handling requirements. For example, the system measures and predicts the traffic density at all en route and oceanic sectors. Dynamic measurements and near-term predictions of each sector’s traffic density are available at that sector. Other traffic measures such as flow rates at relevant fixes are available at surface, arrival/departure, en route, and oceanic sectors and control positions. Other examples of non-flight-specific outputs include DSS schedule information for departures, airborne metering, etc. Although this information contains flight-specific attributes, it primarily provides a non-geographic depiction of traffic spacing, timing, and clustering.

(II) 1.2.2 Monitor non-flight-specific information. Task Objective — Plan general traffic-handling requirements in accordance with predicted demand levels. Background (Sector) — Controllers receive several types of non-flight-specific information that allows them to assess traffic demand. The system measures and predicts the traffic density at all sectors. Dynamic measurements and near-term predictions of each sector's traffic density are available at that sector. Other examples of non-flight-specific outputs include DSS schedule information, and load graphs that indicate demand at selected fixes (e.g., meter fixes, etc.).

Service Provider – Decision Support

1.33b There is also an increased usage of decision support systems that provide both information and heuristics to support the providers in their tasks.

3.5 communications are increasingly automated through the growing availability of datalink, while coordination and planning are aided by new decision support systems. Together, these systems enhance airport safety, improve efficiency and accommodate user preferences.

4.5 Automatic exchange of information between flight deck and ground- based decision support systems improves the accuracy and coordination of arrival trajectories.

4.49 service providers utilize the decision support systems to monitor traffic flows, NAS performance, and weather.

5.10 Decision support systems such as the conflict probe assist the provider in developing safe and effective traffic solutions.

5.11 decision support systems allow more aircraft to operate on routes according to the most favorable winds....with additional available altitudes.

5.15 Additional pilot intent and aircraft performance data are provided to decision support systems, thus improving the accuracy of trajectory predictions. This information is combined and presented on the service provider's display.

5.28 Weather data are distributed to decision support systems for processing and presentation to service providers, resulting in a more accurate and common awareness of meteorological conditions.

5.35 Decision support systems assist in conflict detection and the development of conflict resolutions..

5.38 Use of paper flight strips is eliminated since decision support systems display necessary information.

6.27 The pilot's ability to support climbs, descents, crossing and merging routes is supplemented by the service provider's conflict probe decision support system.

7.12 Enhanced decision support systems improve NAS monitoring, performance measurement, and strategy development.

7.33 Increased collaboration among local facilities, the ATCSCC and NAS users is augmented by decision support systems that enable a shared view of traffic and weather with all parties.

7.36 Improved decision support systems help service providers visualize demand and manage the more complex traffic flows.

7.37 decision support systems that evaluate NAS performance in real-time enable the service provider to be more responsive and to develop more effective traffic management strategies.

7.62 To anticipate where and when demand might exceed capacity, both local and national traffic flow managers rely on decision support systems

7.69 Decision support systems aid the ATCSCC in monitoring user adherence to arrival times.

5.2 Improved decision support tools for conflict detection, resolution, and flow management allow increased accommodation of user-preferred trajectories, schedules, and flight sequences.

(II) New tools enable users to determine the most advantageous flight trajectories, and allow controllers to accommodate them. Since increased user demand and system flexibility result in greater traffic complexity, decision support systems (DSSs) assist controllers and pilots in preventing conflicts with airspace, weather, terrain, and other aircraft.

(II) With tasktime per airplane greatly reduced through the use of task performance aids, controllers have time to handle more traffic than they can conveniently analyze. DSSs therefore assist controllers in their analysis by detecting problems and providing resolutions in the two general areas of traffic planning and conflict detection.

(II) 1.4.5 The system provides `cumulative delay' information that quantifies the total delay an aircraft absorbs throughout its flight. TM DSSs use this information as one variable in the determination of traffic flow sequences.

7.36 Improved decision support systems help service providers visualize demand and manage the more complex traffic flows.

(II) Demand Information — Controllers receive several types of non-flight-specific demand information that enables them to assess current and upcoming traffic handling requirements. For example, the system measures and predicts the traffic density at all en route and oceanic sectors. Dynamic measurements and near-term predictions of each sector's traffic density are available at that sector. Other traffic measures such as flow rates at relevant fixes are available at surface, arrival/departure, en route, and oceanic sectors and control positions. Other examples of non-flight-specific outputs include DSS schedule information for departures, airborne metering, etc. Although this information contains flight-specific attributes, it primarily provides a non-geographic depiction of traffic spacing, timing, and clustering.

(II) 1.3.3.b Tactical clearances are issued as follows: Most tactical clearances require the input of a NAS message to reflect the action in automation. Many of these inputs can be entered using automatically provided input selection options on the flight's data block and/or FIP. These input options are based on information provided by the DMS and other DSSs. For tactical clearances issued via voice, the controller enters the NAS message during clearance issuance and readback. Entry of the NAS message immediately updates the flight's current control information.

Traffic Management – Decision Support

5.47 The traffic flow service provider's role has changed to include coordination of dynamic airspace structuring, more strategic management of traffic, coordination of new trajectories, and the management of major flows.

(II) Implement TM Initiatives Traffic managers and TM DSSs detect demand/capacity imbalances and develop TM Initiatives to address them. These Initiatives consist of NAS configuration changes to optimize capacity, and/or traffic restrictions to modulate demand. Controllers implement NAS Configuration changes, and execute flight-specific control instructions as required to modulate demand.

5.52 Any capacity problems due to SUA schedules, staffing, or weather are identified.

(II) En Route and Arrival Planning. The system automatically determines if predicted demand exceeds the capacities of sectors, routes, and arrival airports. Excess demand is modulated using 1) airborne demand modulation techniques such as metering, miles-in-trail restrictions, or speed restrictions, or 2) departure-point demand modulation using approval requests, ground stops, ground delays, etc. When the capacity of a resource is exceeded, the system provides controllers with the control- action advisories required to implement the demand modulation technique specified by TM. These advisories are usually presented to the controller in the form of input selection options.

(II) 1.3.3 In the planning process described in Task 2.0, traffic managers collaborate with users and coordinate with other traffic managers to determine the actions that will meet the operational objectives of ATC, TM, and users. Based on the decisions that result from this coordination/CDM process, TM DSSs compare demand and capacity at critical resources. When a demand/capacity imbalance exists, TM DSSs develop a Demand Modulation Schedule (DMS) that assesses the times at which individual flights must depart from or arrive at specified resources. To modulate excess demand in accordance with the capacity of each relevant resource, DMS processing proposes traffic routing and sequence, inter- aircraft spacing, and runway assignments. The DMS for a given resource (e. g., an airport, a metering fix, etc.) provides a Demand Modulation Time (DMT) and a Free Flow Time (FFT) for each relevant aircraft. DMTs are assigned to fit demand to capacity.

(II) 1.4.3 For time-based solutions, TM DSSs develop a Demand Modulation Schedule (DMS) that assesses the times at which individual flights must depart from or arrive at specified resources. To modulate excess demand in accordance with the capacity of each relevant resource, DMS processing proposes traffic routing and sequence, inter-aircraft spacing, and runway assignments. The DMS for a given resource (e.g., an airport, a metering fix, etc.) provides a Demand Modulation Time (DMT) and a Free Flow Time (FFT) for each relevant aircraft. DMTs are assigned to fit demand to capacity at affected resources by specifying the times at which flights must push back, depart an airport, cross a departure fix, enter a sector (or a non-U.S. FIR), cross an arrival metering fix, or arrive at a runway. FFTs indicate the time the flight would arrive at the resource under unrestricted operations.

(II)The primary objective of traffic managers is to prevent demand/capacity imbalances that would adversely affect controllers or users beyond the localized areas where the imbalances occur. The tasks required to meet this objective constitute a continuously evolving response to numerous localized conditions throughout the NAS. This requires that traffic managers be provided with accurate and timely knowledge of demand and capacity, and the ability to predict the effects of alternative corrective actions. The framework within which this information is presented consists of specific `NAS resources' that constitute the ATC system.  These resources include airports, runways, sectors, routes, and fixes.  Of all the resources that comprise the NAS, traffic managers are primarily concerned with `critical resources' that generate wide-spread adverse effects when an imbalance occurs. These critical resources represent checkpoints within the NAS where traffic measurements are made by the system, and traffic activity is monitored, assessed, and manipulated by traffic managers.

7.12 Enhanced decision support systems improve NAS monitoring, performance measurement, and strategy development.

(II) 1.3.2 The traffic manager also uses the display to receive DSS information, and to activate flight-specific NAS messages via system-generated input selection options.

(II) 1.3.3 In the planning process described in Task 2.0, traffic managers collaborate with users and coordinate with other traffic managers to determine the actions that will meet the operational objectives of ATC, TM, and users. Based on the decisions that result from this coordination/CDM process, TM DSSs compare demand and capacity at critical resources. When a demand/capacity imbalance exists, TM DSSs develop a Demand Modulation Schedule (DMS) that assesses the times at which individual flights must depart from or arrive at specified resources. To modulate excess demand in accordance with the capacity of each relevant resource, DMS processing proposes traffic routing and sequence, inter- aircraft spacing, and runway assignments. The DMS for a given resource (e. g., an airport, a metering fix, etc.) provides a Demand Modulation Time (DMT) and a Free Flow Time (FFT) for each relevant aircraft. DMTs are assigned to fit demand to capacity. FFTs indicate the time the flight would arrive at the resource under unrestricted operations.

(II) 2.2.1 To achieve this objective, a standardized route configuration in ADCON (Arrival departure control) airspace serves to organize arrivals and departures in the terminal area. However, each arrival and departure routing is provided with several selectable termini lying at increasing distances from the airport. In operation, the system analyzes the prevailing traffic demand, and provides the traffic manager with decision support for determining the points at which arrivals must join their terminal routing, and at which departures may exit their terminal routing.

(II) 3.2.2 TM Initiative Revision & Termination. If the various metrics indicate the need for a revision to the TM Initiative, coordination/CDM participants may use Planner's fast-time analysis capability to evaluate and select alternative responses. With the concurrence of all coordination/CDM participants, demand modulation is terminated when the predicted unrestricted demand falls consistently below the capacity of the impacted resource. Some Initiatives are terminated by specifying the last flight to be subjected to the traffic restriction. When the demand/capacity imbalance has abated and demand modulation is terminated, the Planner is suppressed from the traffic managers' displays, and DSS control information ceases to be routed to ATC control positions.

7.37 decision support systems that evaluate NAS performance in real-time enable the service provider to be more responsive and to develop more effective traffic management strategies.

7.43 Service providers at the ATCSCC develop a NAS-wide understanding of conditions, capacity, and traffic flow to serve as a central point-of-contact for NAS users and local service providers.

(II) 1.0 TM SITUATION AWARENESS To facilitate the traffic manager's maintenance of situation awareness, the system identifies all current conditions and traffic activities both within each facility and throughout the NAS that are relevant to the traffic manager's current decision making. Information on these overall conditions allows national and site traffic managers to judge the timing and nature of relevant traffic flows several hours in advance, as well as the range of options that will likely be available to resolve problems. Capacity information is presented for each resource that is of concern to the traffic manager. This information includes the current configuration and capacity of each resource, as well as the current and predicted conditions that affect the resource's capacity. Traffic information is presented in the form of real time situation information, system-generated demand modulation schedules, and demand and complexity metrics that describe the volume and characteristics of the traffic using NAS resources.

(II) 1.3 EVALUATE CURRENT & PREDICTED DEMAND In the following discussion, traffic managers assess the demand characteristics that result from TM decisions that are already in effect. (Task 2.0 describes the decision making process.) With knowledge of the NAS configuration and capacity information described in previous Tasks, traffic managers evaluate the current and predicted demand on relevant resources. The system provides this demand information through flight- specific and non-flight-specific information. Situation displays provide flight-specific information that enables the traffic manager to visualize the composition and spatial characteristics of the traffic from an ATC perspective. In addition, system-generated demand modulation schedules provide the traffic manager with a chronological view of system-generated traffic sequencing and timing information. Non-flight-specific information includes traffic demand and complexity metrics that enable traffic managers to determine the quantitative impact of the traffic on the facility's resources.

(II) 2.1 RECEIVE SYSTEM-GENERATED NOTIFICATIONS & PLANNING INFORMATION The system provides automatic notifications of imbalances and SUA/weather penetrations. The system also automatically generates a TM Initiative Planner that provides the capabilities required to resolve the condition that generated the alert. These capabilities enable traffic managers to access current, predictive, and historical traffic information, analyze traffic dynamics under alternative conditions, coordinate with other service providers, and facilitate collaborative decision making with users.

7.62 To anticipate where and when demand might exceed capacity, both local and national traffic flow managers rely on decision support systems

For example, areas and times of high demand across the NAS are predicted by identifying optimal wind routes, determined through analysis of upper air winds information. A decision support system helps the service provider evaluate the impact of proposed strategies on the NAS by identifying options for avoiding problematic traffic situations.

7.69 Decision support systems aid the ATCSCC in monitoring user adherence to arrival times.

7.70 To resolve recurrent traffic flow problems, ATCSCC service providers utilize improved automation capabilities for monitoring, measuring and reporting NAS performance.

This automation includes decision support systems for developing alternative airspace designs, simulating traffic through the NAS for each airspace structure proposal, and evaluating each proposal.

Controller Workload

1.15 Traffic demand increases significantly without a corresponding increase in the controller workforce.

3.10 continuous updating of the flight object improves real-time planning for both the user and the service provider....improves the effectiveness of ongoing traffic management initiatives and the collaborative decision making.

4.49 service providers utilize the decision support systems to monitor traffic flows, NAS performance, and weather.

5.10 Decision support systems such as the conflict probe assist the provider in developing safe and effective traffic solutions.

7.13 Automation and decision support capabilities tailored for the ATCSCC facilitate coordination among local and national traffic flow managers to improve decision making.

7.36 Improved decision support systems help service providers visualize demand and manage the more complex traffic flows.

7.37 decision support systems that evaluate NAS performance in real-time enable the service provider to be more responsive and to develop more effective traffic management strategies.

7.62 To anticipate where and when demand might exceed capacity, both local and national traffic flow managers rely on decision support systems

1.16 Controller workload under peak traffic remains equivalent to the workload controllers absorbed in the 1990s under lighter traffic demand. This increased ATC efficiency has been achieved through the implementation of decision support systems for traffic management and control, dynamic alteration of airspace boundaries, reduced vertical separation minima, improved air/ground communications and coordination, and enhanced ground/ground coordination aids.

3.5 communications are increasingly automated through the growing availability of datalink, while coordination and planning are aided by new decision support systems. Together, these systems enhance airport safety, improve efficiency and accommodate user preferences.

4.20 Decision support systems help service providers to maintain situation awareness, identify and resolve conflicts, and sequence and space arrival traffic.

4.49 service providers utilize the decision support systems to monitor traffic flows, NAS performance, and weather.

5.10 Decision support systems such as the conflict probe assist the provider in developing safe and effective traffic solutions.

5.11 decision support systems allow more aircraft to operate on routes according to the most favorable winds....with additional available altitudes.

5.15 Additional pilot intent and aircraft performance data are provided to decision support systems, thus improving the accuracy of trajectory predictions. This information is combined and presented on the service provider's display.

5.28 Weather data are distributed to decision support systems for processing and presentation to service providers, resulting in a more accurate and common awareness of meteorological conditions.

5.35 Decision support systems assist in conflict detection and the development of conflict resolutions..

5.38 Use of paper flight strips is eliminated since decision support systems display necessary information.

5.66 increased information exchange between the en route, arrival, departure and surface decision support tools enables better coordination

6.27 The pilot's ability to support climbs, descents, crossing and merging routes is supplemented by the service provider's conflict probe decision support system.

7.12 Enhanced decision support systems improve NAS monitoring, performance measurement, and strategy development.

7.13 Automation and decision support capabilities tailored for the ATCSCC facilitate coordination among local and national traffic flow managers to improve decision making.

7.33 Increased collaboration among local facilities, the ATCSCC and NAS users is augmented by decision support systems that enable a shared view of traffic and weather with all parties.

7.36 Improved decision support systems help service providers visualize demand and manage the more complex traffic flows.

7.37 decision support systems that evaluate NAS performance in real-time enable the service provider to be more responsive and to develop more effective traffic management strategies.

7.62 To anticipate where and when demand might exceed capacity, both local and national traffic flow managers rely on decision support systems

7.69 Decision support systems aid the ATCSCC in monitoring user adherence to arrival times.

5.41 For VFR aircraft automatically reporting their satellite-derived positions … coupled with access to the flight's data via the NAS-wide information system, reduces the workload associated with providing traffic advisories to uncontrolled aircraft.

(II) 1.2 Flight-specific information is delivered to the sector well before each flight arrives at the sector or departs from the airport. In the aggregate, this information describes the overall characteristics (e.g., route mixture, type mixture, general flows, etc.) of the approaching traffic. Non-flight-specific information is provided by TM DSSs that generate various types of traffic loading, scheduling, and delay information.

Advisories to Controllers

(II) 1.4 MAKE CONTROL DECISIONS & IDENTIFY REQUIRED TASKING As the final stage of maintaining situation awareness, the ECON controller makes control decisions and determines the tasking required to implement them. To assist in the controller's decision making and task identification, the system provides 1) automatic and on-request conflict detection and resolution, 2) task prompts for time-constrained tasking, 3) TM information and control advisories, 4) user-preferred trajectory information, and 5) flight-specific delay data. Based on these aids and information, the controller makes decisions and identifies tasks that will assure air safety, meet procedural requirements and TM Initiatives, and maximize conformance to user-preferred trajectories. The following tasks describe this decision making and task identification process in the ECON environment.

5.9.2 New displays are operational in all en route facilities and the service provider has access to more accurate forecasts of potential conflicts.

(II) FIPs (Flight Information Profile) These information outputs make all relevant flight object data available to the controller. Data relevance is defined by the facility for each sector or control position. The overall flight object data set includes flight profile information, track data, task prompts, coordination information, and conflict warnings and descriptions. It also includes system-generated input selection options for procedural tasks, conflict resolution options, controller preplanning, and DSS control action advisories. This information may be displayed in any of several forms, as illustrated by the following examples: 1) FIPs can be output in tabular form in a dedicated window. This window can be divided into sub- windows, or `bays.' Using this scheme, FIPs are time-sequenced into the bays in the same manner as present day strips. 2) Upon controller request, a FIP can be output in association with the track on the situation display, to provide a `fully expanded data block' capability. 3) FIP information may be out put graphically, using either a geographical or time base. Geographically based FIP information may be output on the primary situation display or in a dedicated window. Time-based graphical information is output in a dedicated window.

(II) Situation Display This display provides a real time graphical depiction of the airborne and/or surface traffic conditions that are relevant to the control position. The graphical depiction includes all information that is provided by today's en route and arrival/departure situation displays, such as sector or airport map data, weather, surveillance targets, aircraft position indicators, track projections, and data blocks. However, the presentation of these types of information is enhanced in 2005 to facilitate their assimilation by the controller, and additional types of information are also provided to assist in the controller's situation awareness/analysis. These additional types of information include the task performance aids and DSS outputs discussed above (e.g., datalink messages, silent coordination information, task prompts, traffic planning control-action advisories, conflict warnings, conflict descriptions, conflict resolution options, system-generated input selection options, etc .).

(II) In all control environments, FIPs and situation displays enable controllers to remain aware of all flight-specific activities, (e.g., datalink messaging, time-constrained tasking, conflict warnings & resolutions, etc.) without diverting their attention to single-use secondary displays. In addition, they accommodate most of the controller's message input needs by providing single-stroke, multiple- action input selections, which reduces reliance on a keyboard-driven command language. Input selection options from all sources (DSSs, conflict probe, controller preplanning, etc.) are checked for conflicts, and an input option is either disabled or flagged for the controller's attention if the entry of that option will create a conflict.

(II) When a conflict is detected for a datalink-equipped flight, the system may generate pre-loaded input selection options for three alternative resolutions. In this example, each option consists of a heading, an altitude, and a pointout to another sector. These input selection options are displayed on the flight's FIP, or in association with its data block on the situation display.

(II) 1.3.1 Current traffic is depicted on the situation display and on each flight's FIP. This information combines and expands upon the information traditionally provided by data blocks and flight progress strips, and integrates the data provided by various NAS components such as conflict probe, datalink, TM DSSs, etc.

(II) 1.3.1 Situation display — Primary: Airspace maps, track positions, call signs, flight status (IFR, non-flight-followed VFR, flight followed VFR), conflict warnings, task prompts, infrastructure and SUA event prompts, and SUA status. Secondary: Terrain maps, track projections (vector lines, halos, route readouts, etc.), conflict & conflict resolution descriptions, and weather. Situation display and/or FIP — Primary: Call signs, the other controller's preplanning on received pointouts, the other controller's responses to pointouts made to those sectors, handoff indicator, forced information forwarded from another sector. Secondary: Flight-specific input selection options, sector-entry times, current and assigned headings, altitudes, and speeds (IAS and Mach), current groundspeed, altitude profile data ('next requested altitude,' etc.), flight condition indicators (emergency, hijack, etc.), datalink message content, unacknowledged datalink clearance indicator, conflict warnings, full conflict and resolution information, TM DSS advisories (headings, altitudes and speeds), aircraft non-conformance indicators, pilot self-separation indicators, infrastructure and SUA event prompts, task prompts (handoff, communications transfer, unacknowledged datalink clearances, objectively time-constrained control actions, etc.), coordination information (sector in possession of the track, sector in communications with the flight, the level of control requested/received by one sector while the flight is in another sector's airspace, preplanned actions by the controlling sector, pointout responses by all sectors, the identities of all sectors observing the flight, etc.).

(II) 1.4.1 When a terrain, weather, or SUA conflict is predicted, the system automatically provides an indication to the controller. The identity of the relevant SUA is automatically indicated on the flight's data block and/or FIP. Upon controller request, the system displays SUA status and schedule information, and the location and time at which a terrain, weather, or SUA conflict will occur.

(II) 1.4.1   The system provides resolution options for aircraft, terrain, weather, and SUA conflicts that are detected through automatic or on- request probing. These resolutions may utilize reroutes, procedural restrictions, or surveillance control techniques. Resolutions requiring a climb are validated based on temperature/pressure aloft, aircraft weight, and the users' operating characteristics and altitude-profile requests. The system-generated resolutions are displayed as input selection options on the FIP and/or data block of the applicable flight.

(II) 1.4.3 Sector Information.   Relevant time-based and trajectory-based information are output on the sector's displays. DMTs, MIT restrictions, or explicit control action advisories (speeds, altitudes, headings/routings, and runway assignments required for each flight to achieve its TM Initiative requirement). These types of control information are presented on the data blocks and/or FIPs of the appropriate flights. System-generated task prompts are provided for control actions that are objectively time-constrained. The controller may also view the DMS for a relevant resource in various flight-specific forms, such as lists and timelines, for example. Lists may be comprised of FIPs for each aircraft using the resource of interest, organized per sector definition. Timelines at specified resources represent another graphical means of presenting chronological DMS information. These types of outputs may present information such as the aircraft callsign, its DMT and FFT at the applicable resource, or other site-adapted information.

2.2 Elements of the NAS-wide information system are used to obtain and distribute flight-specific data and aeronautical information, including international coordination of flight trajectory content.

5.61 The use of the NAS-wide information system and the flight object means that any changes in the NAS airspace structure … ripple back through the information system and identify all flights whose trajectories penetrate the changed airspace.

(II) 1.2 Flight-specific information is delivered to the sector well before each flight arrives at the sector or departs from the airport. In the aggregate, this information describes the overall characteristics (e.g., route mixture, type mixture, general flows, etc.) of the approaching traffic. Non-flight-specific information is provided by TM DSSs that generate various types of traffic loading, scheduling, and delay information.

Separation Assurance

1.17 Air safety has been increased through the implementation of conflict detection and resolution tools, the inclusion of the flight deck in some separation decision-making, and greatly enhanced weather detection and reporting capabilities.

5.2 Improved decision support tools for conflict detection, resolution, and flow management allow increased accommodation of user-preferred trajectories, schedules, and flight sequences.

5.28 Weather data are distributed to decision support systems for processing and presentation to service providers, resulting in a more accurate and common awareness of meteorological conditions.

5.30 As in the departure and arrival operations, increased decision support allows significant improvement in en route separation assurance.

5.35 Decision support systems assist in conflict detection and the development of conflict resolutions..

1.20 Redistributed Roles and Responsibilities. Separation assurance remains the responsibility of the service provider. However, that responsibility is shifted to the flight deck for specific operations.

4.20 Decision support systems help service providers to maintain situation awareness, identify and resolve conflicts, and sequence and space arrival traffic

4.21 Separation assurance has undergone changes in the following areas: aircraft-to-aircraft separation, aircraft-to-airspace and aircraft-to- terrain/obstruction separation ....

5.30 As in the departure and arrival operations, increased decision support allows significant improvement in en route separation assurance.

Trajectory Prediction

5.15 Additional pilot intent and aircraft performance data are provided to decision support systems, thus improving the accuracy of trajectory predictions. This information is combined and presented on the service provider's display.

User-Preferred Trajectories

5.19 flights routinely operate on user-preferred trajectories, with fewer aircraft constrained to a fixed route structure. These trajectories are accommodated earlier in the flight and continue closer to the destination than is currently allowed.

2.2.1 Aircraft Routings. User-preferred trajectories are generally accommodated in ECON airspace, and trajectory entry and egress are accomplished as near to the departure and arrival airports as prevailing traffic factors allow. To achieve this objective, a standardized route configuration in ADCON airspace serves to organize arrivals and departures in the terminal area. However, each arrival and departure routing is provided with several selectable termini lying at increasing distances from the airport. In operation, the system analyzes the prevailing traffic demand, and provides the traffic manager with decision support for determining the points at which arrivals must join their terminal routing, and at which departures may exit their terminal routing.

E. Information Dissemination

Timely information dissemination and delivery validation improvements can enhance efficient and effective airspace use. Operational difficulties arising from the failure to deliver critical information are avoided by the inclusion of automated and semi-automated processes.

The processes of information delivery and validating the receipt of pertinent information can be improved. The chain of information exchange is not complete in some cases and a system to validate the receipt of this data is in need.

The primary goal is to avoid occurrence of operational constraints caused by the failure of a pilot, controller, AOC or other stakeholder to receive route-critical information. This general problem has safety and transition airspace implications, but the point of interest is its significance in the constrained en route domain.

Although the immediate affect in the examples involves only one aircraft, the information delivery failure is incipient. It is significant beyond the one-aircraft, one-incident to include cascading effects of increased work load and airspace loading. Had the events occurred at or near congested airspace, for example, the affect could include a precipitous increase in the controller and pilot workload and disruption of traffic flow to deal with an emergency.

The problem bounds are:

Flight Domain: Post departure while in en route airspace. Terminal airspace constraints are not relevant.

Time Domain: All time horizons are under consideration. The examples all are such that the needed information is available well before the incident, but even a 10-minute advance notice could have been used effectively.

Stakeholders: The main influence is on those directly responsible for operation within the designated flight domain (primarily controllers and pilots).

Factors: Information is available which is relevant to safe and efficient operation to a flight or flights. The criticality of the information varies. This information could be weather, sector loading, SUA opening or closing, or Navigational Aid (NAVAID) status as examples.

Failure: The critical information is not delivered. It is assumed that the information directly relevant to a flight or flights in the designated domain is developed, available, and timely.

Delivery is more than dissemination. Delivery presumes receipt of the disseminated information. In fact, delivery connotes timely receipt by whomever (e.g., pilot, controller, or AOC) needs the information. Confirmation of receipt is necessary in many cases, based on the criticality of information.

The three examples meet these bounds, had significant results, and the National Transportation Safety Board (NTSB) found that the system and individuals all acted within their regulatory limits.

Examples

The examples show the impact of the failure to provide timely delivery of information in three cases. The failure in each case is the result of the weakness in the underlying system architecture that receipt of the critical information requires initiative by the pilot and controller that is not otherwise required by the situation.

The weather Information Dissemination Architecture from the pilot and controller's perspective are shown in Figures 6 and 7 respectively.   The SUA (Special Use Airspace) information dissemination architecture is shown in Figure 8.

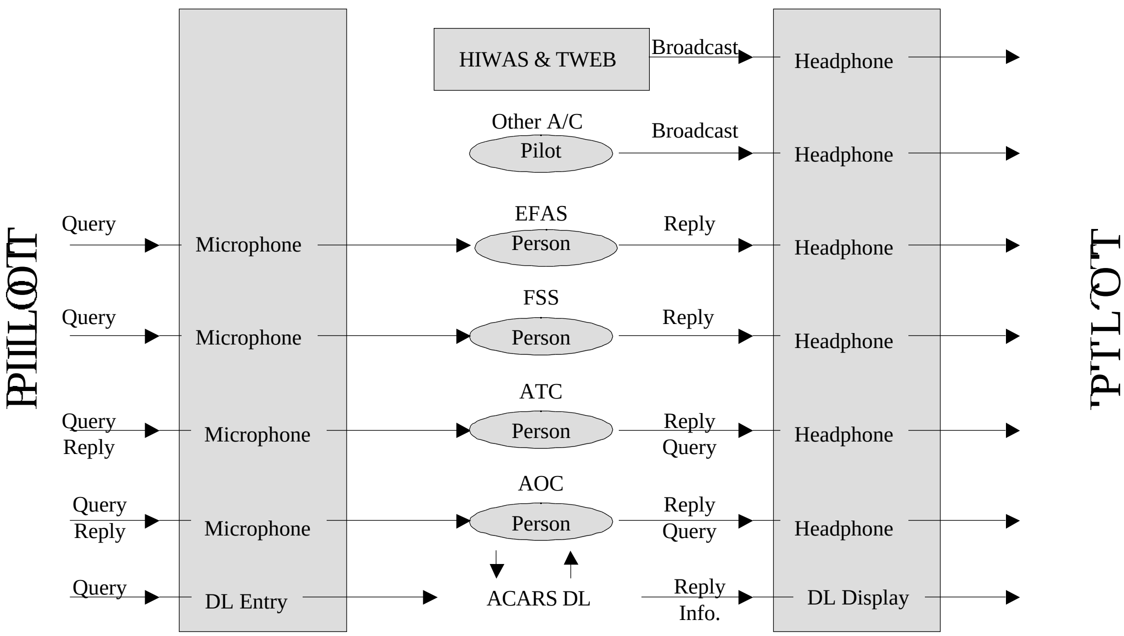


Figure 6 Weather Information Dissemination - Pilot Centered

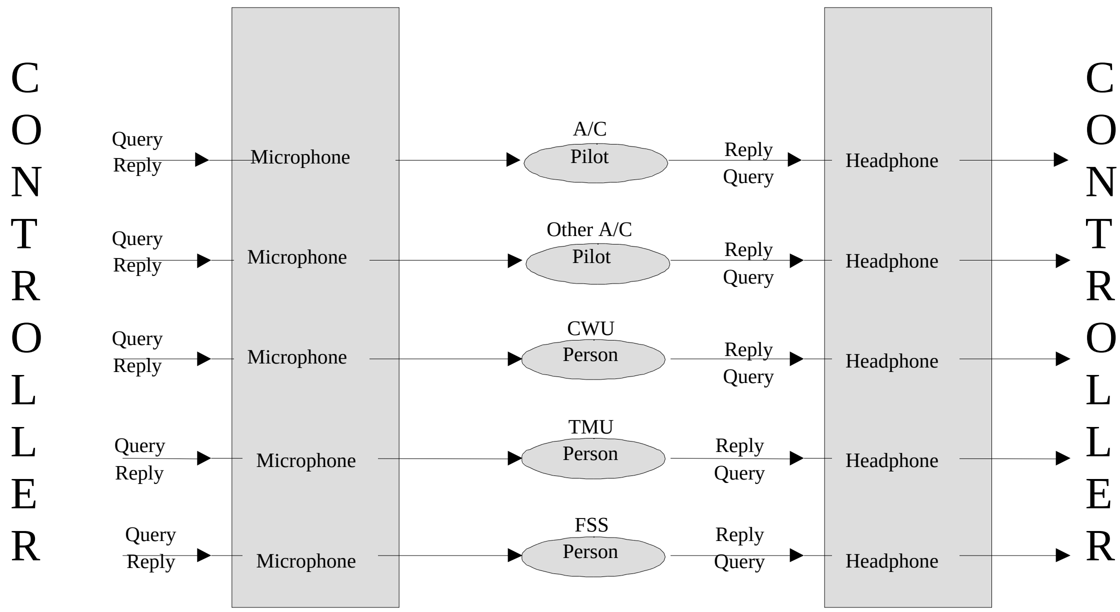


Figure 7 Weather Information Dissemination - Controller Centered

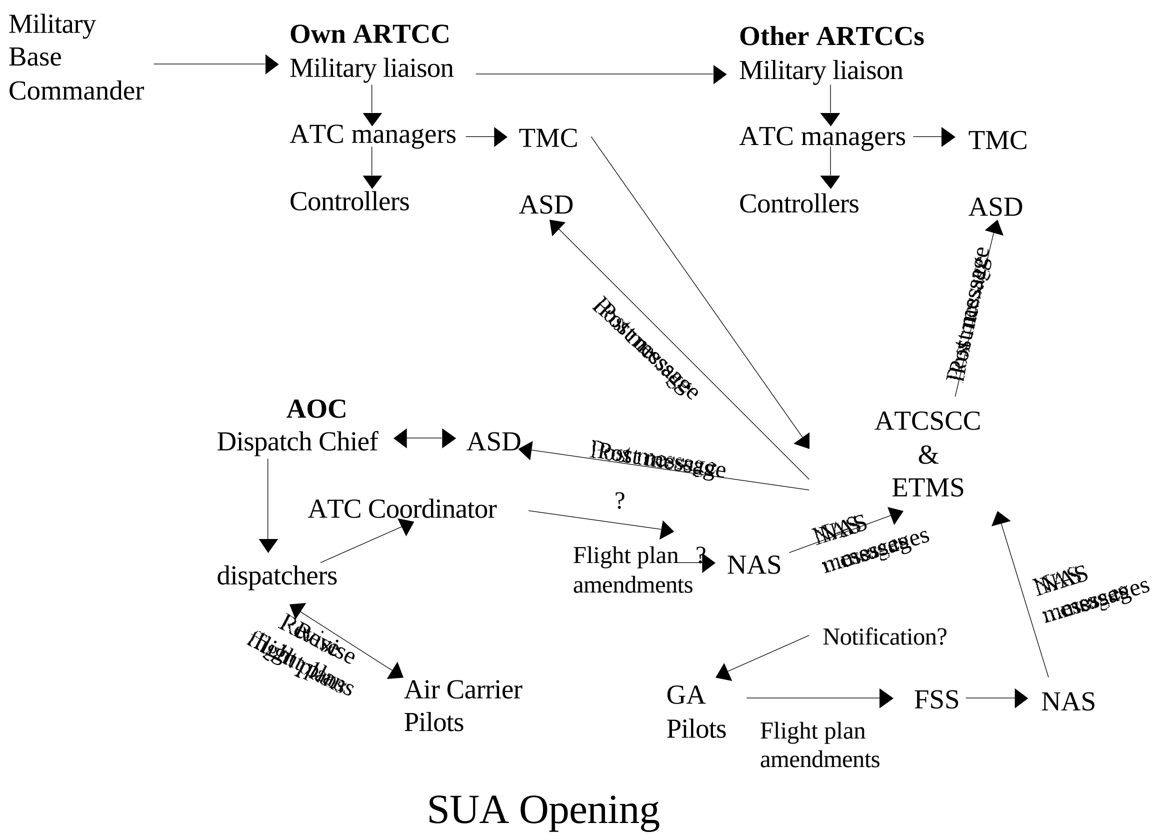


Figure 8 SUA Information Dissemination

Example 1: Critical Information Not Delivered

This incident involved American Airlines Flight 869, an Airbus A-300B on January 17th, 1996. The flight was being operated as a scheduled, Part 121 operation between Miami, Florida and San Juan, Puerto Rico. The flight was en route at FL350 when it encountered severe turbulence and caused minor damage to the aircraft. The aircraft's Flight Data Recorders measured a vertical acceleration of +2.088G's to -1.032 G's to 1.788G's in a short period of time. In addition, seventeen passengers received minor injuries and three passengers received serious injuries.

The crew remarked after the incident that they had not remembered "anything remarkable" in their weather information received by the American Airlines dispatchers prior to take off. The crew also noted they had not received any warnings of SIGMETs or AIRMETs along their route of flight. The NTSB, upon completion of their investigation into the weather received by Flight 869, discovered that indeed there was no mention of severe weather warnings in the briefing package issued to the crew. Although, at the time of the incident there was a SIGMET in effect for the route of flight for 869. At 1236 Zulu time that day, prior to the departure time of flight 869 of 1401 Zulu from Miami, the National Weather Service had issued SIGMET Echo. The SIGMET stated that satellite images showed an area of active thunderstorms with echo tops to 38,000 feet in the area of the incident. This severe weather warning was in effect to 1640 zulu.

The crew of 869 clearly stated that they had not received this SIGMETs in the weather information provided by American's dispatch prior to departure. American Airlines produces customized weather briefing packages to its crew members through the FAA's Enhanced Weather Information System.

The breakdown of information delivery involved many factors. First, the crew's incomplete weather briefing package provided by the company. Second, the failure to monitor the broadcasts of the warnings for their route of flight. Third, "the crew stated they did not hear it broadcast on the normal ATC communications frequencies," perhaps indicating that service providers were not properly notifying aircraft under their jurisdiction of adverse weather.

Example 2: Failure To Deliver Icing Information Causes Accident

This scenario was a high profile case involving the de-icing system on several popular regional aircraft flown throughout the world, the ATR-72. On October 31,1994 an ATR-72 operated by American Eagle Flight 4184 crashed after encountering severe icing conditions over Roselawn, Indiana. The safety issues of the NTSB accident investigation focused on communicating hazardous weather information to flight crews. During the course of events leading up to this fatal accident, several missing links in the information exchange system existed. For example, missing warnings about possible icing conditions along the route of flight were not received and standard pilot reports (UAs) were not reported to sector controllers in the Chicago Air Route Traffic Control Center (ARTCC). The following were some of the dissemination issues from the report:

"Safety would be enhanced if the hazardous in-flight weather advisory service (HIWAS) information were presented more consistently and had included all of the information pertinent to the safety of flight…." (NTSB 1996, p.2).

"Continued development of equipment and computer programs to measure and monitor the atmosphere could permit forecasters to refine weather data sufficiently to produce real-time warnings that define specific locations of atmospheric icing conditions (including freezing drizzle and freezing rain) and could enable forecasters to produce short range forecasts ("nowcasts") that identify icing conditions far a specific geographic area with a valid time of 2 hours or less." (NTSB 1996 p.2)

The following are some of the recommendations related to information dissemination that the NTSB made to the FAA at the completion of the accident investigation:

"Direct principal operations inspectors (POIs) to ensure that all 14 Code of Federal Regulations (CFR) Part 121 air carriers require their dispatchers to provide all pertinent information, including airman's meteorological information (AIRMET) and Center Weather Advisories (CWAs), to flightcrews for preflight and in-flight planning purposes." (NTSB 1996 p.5)

"Require that Hazardous In-Flight Weather Advisory Service (HIWAS) broadcasts consistently include all pertinent information contained in weather reports and forecasts, including in-flight weather advisories, airman's meteorological information (AIRMETs), significant meteorological information (SIGMETs), and Center Weather Advisories (CWA's)" (NTSB 1996 p.6)

"Revise FAA Order 8400.10, Chapter 7, Section 2, paragraph 1423 (Operational Requirements-Flightcrews) to specify that Center Weather Advisories (CWAs) be included and considered in the flightcrew's preflight planning process." (NTSB 1996 p.7)

NTSB Recommendation to AMR Eagle after completion of the accident report:

"Require dispatchers to include in the flight release airman's meteorological information (AIRMETs) and center weather advisories (CWAs) that are pertinent to the route of flight so that flightcrews can consider this information in their preflight and in-flight decisions." (NTSB 1996 p.7)

Example 3: Failure To Disseminate Results In Flights Through Undesirable Areas

A commuter flight from Charlotte N.C. to Tri-City Regional Airport, TN encountered severe turbulence that could have been avoided.

The pilot did not receive a complete weather briefing affecting the proposed route of flight in the pilot briefing from the AOC. The pilot had flown the reverse route earlier the same day and did encounter moderate Clear Air Turbulence. However, since the previous flight, the turbulence had increased in severity from occasional moderate to occasional sever turbulence; in turn a CWA was issued. The pilot did not receive the CWA in the briefing packet provided by the company and therefore was not aware of the increased intensity of the turbulence. The NTSB had discovered that the CWA issued by the weather service units was missing from the out station's weather information service provider (in this case a private contractor).

In general terms, passengers were injured, the controller and pilot focused significant effort or resolving the incident, and no fault with either the pilot or controllers was identified.

The failure was that route-critical information that had been developed had not been delivered. Confirmation of delivery at the AOC is not required. Additionally, both the controller and the pilot could have obtained the critical information by making an inquiry (see Figure 6 and 7). There is no push of this information the users so that a query is necessary.

Impact and Considerations

The information dissemination problem for constrained airspace is the failure of timely delivery of existing route-critical information to either the pilot, responsible controller, or other stakeholder enabled to resolve the impending difficulty. Route-critical information is any information necessary to galvanize action that will result in an improved routing of a flight or flights.

Impact on users:

- Had the crew been made aware of the significant weather warning, alternate routings could have been planned to avoid that portion of the route that was affected by the turbulence.

- As a result of the lack of complete knowledge of weather along the route of flight, the aircraft did encounter severe turbulence resulting in injury to several passengers and crewmembers.

Priorities of User Agent (Pilot/AOC)

- Crews of Part 121 operators as well as pilots operating under part 91 of the federal aviation regulations are required to be familiar with all pertinent information to conduct safe flight operations. (see FAR 91.103 & FAR 121.101)

- There are also Federal Regulations addressing the responsibilities of air carriers and dispatchers to provide a system for obtaining and disseminating weather data pertinent to the safety of flight. (see FAR 121.101, 121.99, and 121.125) Air carriers are obligated to use only FAA approved sources for weather data. If these sources of data are missing severe weather products as part of crew briefing packages, then incidents such as this may happen in the future.

Impacts to ATM System

- The injury created an emergency condition which causes an increased workload on air traffic controllers. Priority handling of the subject aircraft could very likely require other aircraft to be vectored out of their normal routes in order to accommodate the aircraft with the injured person on board. This again causes increased workload to traffic management specialists as well as sector controllers.

<u>Considerations/Priorities/ Responsibilities of ATM Agents</u>

The FAA Order 7110.65, *Air Traffic Controllers Handbook,* specifically addresses procedures for controllers regarding dissemination of hazardous weather information by the use of a broadcast over all frequencies under their jurisdiction. However, there is no specific requirement for the controller to insure that the pilot actually received that broadcast. There is no specific requirement for the controller to communicate the weather information to individual flights.

F. NOTAMS and Weather Reports

The material in this appendix is extracted from the Aeronautical Information Manual (AIM). Each extract is relevant to some previously discussed problem area.

Notices to Airmen (NOTAMs) -

Available NOTAM (D) information pertinent to the proposed flight. NOTAM (L) information pertinent to the departure and/or local area, if available, and pertinent FDC NOTAMs within approximately 400 miles of the Flight Service Station (FSS) providing the briefing. Automated Flight Service Stations (AFSS) facilities will provide FDC NOTAMs for the entire route of flight

NOTAM (D) information and FDC NOTAMs which have been published in the Notices to Airmen publication are not included in pilot briefings unless a review of this publication is specifically requested by the pilot. For complete flight information you are urged to review the printed NOTAMs in the Notices to Airmen publication and the Airport/Facilities Directory in addition to obtaining a briefing.

Section 7-1-5 of the AIM-INFLIGHT WEATHER ADVISORIES

The National Weather Service (NWS) issues in-flight weather advisories designated as Severe Weather Forecasts Alerts (AWW), Convective SIGMETs (WST), SIGMETs (WS), Center Weather Advisories (CWA), and AIRMETs (WA). These advisories are issued individually; however, the information contained in them is also included in relevant portions of the Area Forecast (FA). When these advisories are issued subsequent to the FA, they automatically amend appropriate portions of the FA until the FA itself has been amended. In-flight advisories serve to notify en route pilots of the possibility of encountering hazardous flying conditions which may not have been forecast at the time of the preflight briefing. Whether or not the condition described is potentially hazardous to a particular flight is for the pilot and/or the aircraft dispatcher in a (FAR 121) operation to evaluate on the basis of experience and the operational limits of the aircraft.

AWWs are preliminary messages issued in order to alert users that a Severe Weather Bulletin (WW) is being issued. These messages define areas of possible severe thunderstorms or tornado activity. The messages are unscheduled and issued as required by the Aviation Weather Center at Kansas City, Missouri.

WSTs concern only thunderstorms and related phenomena (tornado, heavy precipitation, hail, and high surface winds) over the conterminous United States and imply the associated occurrence of turbulence, icing, and convective low level windshear. WST are issued for any of the following phenomena:

Convective SIGMET Bulletins -

1. Three Convective SIGMET bulletins, each covering a specified geographic area, are issued. These areas are the Eastern (E), Central (C), and Western (W) U.S. The boundaries that separate the Eastern from the Central and the Central from the Western U.S. are 87 and 107 degrees West, respectively. These bulletins are issued on a scheduled basis, hourly at 55 minutes past the hour (H+55), and as special bulletins on an unscheduled basis.

On an hourly basis, an outlook is made for each of the three Convective SIGMET regions. The outlook for a particular region is appended to the Convective SIGMET bulletin for the same region. The convective outlook is also appended to special Convective SIGMETs. The outlook is reviewed each hour and revised when necessary. The outlook is a forecast and meteorological discussion for thunderstorm systems that are expected to require Convective SIGMET issuance's during a time period 2 to 6 hours into the future. Furthermore, an outlook will always be made for each of the three regions, even if it is a negative statement.

SIGMETs within the conterminous U.S. are issued by the Aviation Weather Center when the following phenomena occur or are expected to occur:

1. Severe or extreme turbulence or clear air turbulence not associated with thunderstorms.

2. Severe icing not associated with thunderstorms.

SIGMETs are identified by an alphanumeric designator which consists of an alphabetic identifier and issuance number. The first time an advisory is issued for a phenomenon associated with a particular weather system, it will be given the next alphabetic designator in the series and will be numbered as the first for that designator. Subsequent advisories will retain the same alphabetic designator until the phenomenon ends. In the conterminous U.S., this means that a phenomenon that is assigned an alphabetic designator in one area will retain that designator as it moves within the area or into one or more other area. Issuances for the same phenomenon will be sequentially numbered, using the same alphabetic designator until the phenomenon no longer exists. Alphabetic designators NOVEMBER through YANKEE, except SIERRA and TANGO are only used for SIGMETs, while designators SIERRA, TANGO and ZULU are used for AIRMETs.

The CWA is an unscheduled in-flight, flow control, air traffic, and aircrew advisory. By nature of its short lead-time, the CWA is not a flight-planning product. It is generally a "nowcast" for conditions beginning within the next 2 hours. CWAs will be issued:

1. As a supplement to an existing SIGMET, Convective SIGMET, AIRMET, or FA.

2. When an In-flight Advisory has not been issued but observed or expected weather conditions met SIGMET/AIRMET criteria based on current pilot reports and reinforced by other sources of information about existing meteorological conditions.

3. When observed or developing weather conditions do not meet SIGMET, Convective SIGMET, or AIRMET criteria; for example, in terms of intensity or area coverage, but current pilot reports or other weather information sources indicate that existing or anticipated meteorological phenomena will adversely affect the safe flow of air traffic within the ARTCC area of responsibility.

WAs may be of significance to any pilot or aircraft operator and are issued for all domestic airspace. They are of particular concern to operators and pilots of aircraft sensitive to the phenomena described and to pilots without instrument ratings and are issued by the AWC for the following weather phenomena which are potentially hazardous to aircraft:

1. Moderate icing.

2. Moderate turbulence.AIRMETs are issued on a scheduled basis every six hours, with unscheduled amendments issued as required. AIRMETs have fixed alphanumeric designator with ZULU for icing and freezing level data, TANGO for turbulence, strong surface winds, and windshear, and SIERRA for instrument flight rules and mountain obscuration.

Each CWA will have a phenomenon number (1 - 6) immediately following the ARTCC identifier. This number will be assigned to each meteorologically distinct condition or conditions; for example, jet stream clear air turbulence or low IFR and icing northwest of a low pressure center, meeting CWA issuance criteria. Following the product type (CWA) a two digit issuance number will be entered starting at midnight local each day. In addition, those CWAs based on existing non-convective SIGMETs/AIRMETs will include the associated alphanumeric designator; for example, ALPHA 4.Status reports are issued as needed on Severe Weather Watch Bulletins to show progress of storms and to delineate areas no longer under the threat of severe storm activity. Cancellation bulletins are issued when it becomes evident that no severe weather will develop or that storms have subsided and are no longer severe.

G. Special Use Airspace

Special Use Areas include Restricted Areas, Prohibited Areas, Warning Areas, and Military Operations Areas (MOA); all operate under the aegis of the DoD. The Federal Aviation Regulations (FARs) and aviation maps identify the operational constraints on these areas. Approximately 25% of the airspace in the continental United Sates is considered an SUA.

This appendix collects a number of SUA factors relevant to constrained en route operations. It is organized into four sections:

- Observations About Current Restricted Areas and Warning Areas
- White Sands Missile Range (WSMR) SUAs
- Attributable To Flexible SUA Use
- MAMS, SAMS, and OASIS

G.1 OBSERVATIONS ABOUT CURRENT RESTRICTED AREAS AND WARNING AREAS

This is a collection of quotes regarding SUAs which are taken from references listed in Appendix A .

- " In fact most of today's SUA was created during the 1960's and 1970's and does [sic] not reflect the operational capabilities or requirements of today's weapons systems." (Rock, p.4)
- "American Airlines discussed the optimal times for notification concerning SUA. At about four hours before departure, the potential routes of flight are scanned for optimal winds. Approximately 1 hr and 10 minutes prior to departure a final route calculation is computed for the flight and the aircraft is fueled appropriately for this route. It is at this time that knowledge of SUA status is most critical." (Bayles, 1997)
- " The results of the comparisons of economic benefits for different flight scenarios are summarized in Table 2 [table not included in this document] below. Only 7,566 of the 33,271 IFR flights/day in the schedule had corresponding ATC preferred routes. These 7,566 flights were first assumed to fly on ATC preferred routes, then on shortest routes avoiding all SUAs and finally on direct routes. The difference in distances flown between ATC preferred routes and direct routes for all 7,566 flights was 220,000 nm per day. This corresponds to a potential, daily operating cost savings of $693,000 and a potential annual operating cost savings of $253 million. In a previous study (Couluris and Dorsky, 1995), the savings from user-optimized routes with access through SUAs was estimated to be $332 million/year." (Datta, p.7)
- "Maximum Economic Benefit of Dynamic Use of all SUAs.

The results of the analysis of maximum economic benefit of dynamic use of SUAs are summarized in Table 3 [table not included in this document] below. When all 33,271 IFR flights/day on 6,818 routes in the schedule were flown on the shortest routes avoiding SUAs only 16% of the flights and only 18% of the routes were affected by SUAs. For flights on these routes, the total of the differences in distances flown between shortest routes avoiding SUAs and direct routes was 7,000 nm. This corresponds to a potential daily and annual operating cost savings of $21,000 and $7.8 million, respectively. This result quantifies objective 2 of this paper: the maximum economic benefit of dynamic use of SUAs is about $7.8 million annually. From the IFR schedule, the route with the maximum savings benefit ($ 520,000 annually) is the Phoenix, AZ to San Francisco, CA route, while the route with the maximum distance savings (25 nm) is the Las Vegas, NV to San Luis Obispo, CA route." (Datta, p.9)

G.2 WHITE SANDS MISSILE RANGE (WSMR) SUAs

The WSMR SUA is located in New Mexico just south of Albuquerque and extends almost to the USA/Mexico border. It lies within the confines of the Albuquerque ARTCC (ZAB) east of Los Angeles and west of Dallas. It is approximately 100 miles wide and 200 miles long. Vertical limits range from the surface to FL600. These vertical dimensions do vary since there are several restricted areas within the main block of airspace with varying altitude restrictions, however for all intents and purposes the entire block is not available for commercial use Monday through Friday from 0600 to 2300 Mountain Time. The extract from the NOAA IRF ENROUTE HIGH ALTITUDE - U.S." is in Figure 9 .

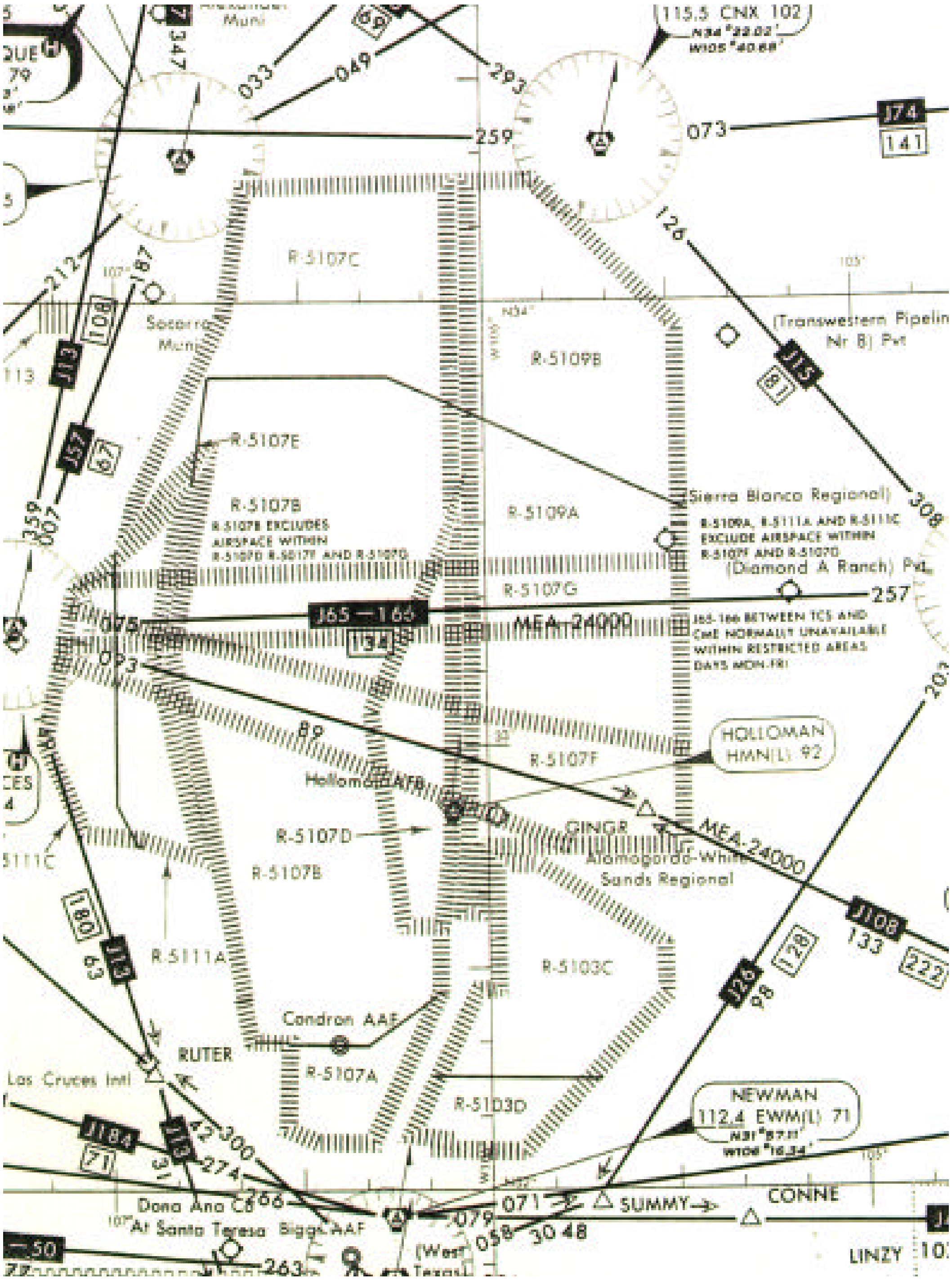


Figure 9 **White Sands Missile Range (WSMR)**

The process of opening an SUA is illustrated in Figure 10 .

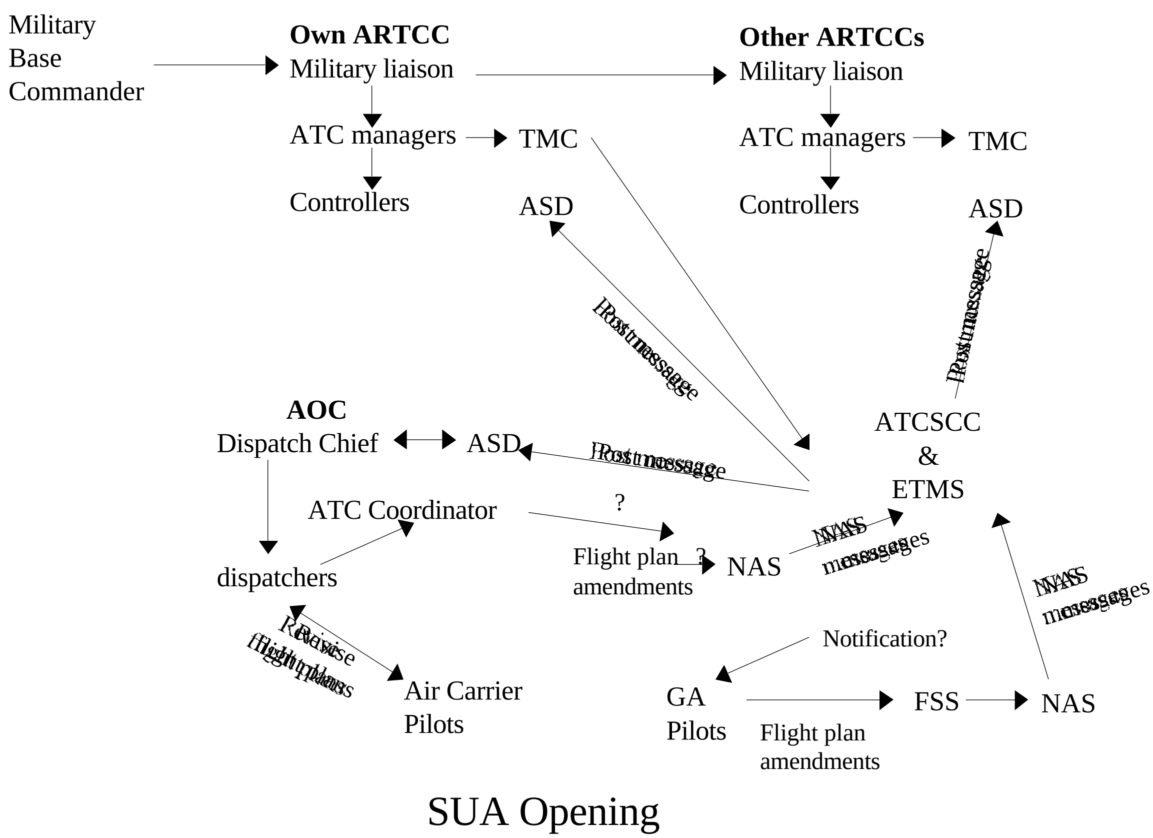


Figure 10 SUA Activation Process

There is a narrow corridor of airspace in which high altitude jet route J65/ J166 are routed. These airways are not available for use at any altitude except during weekend days. The WSMR is under the jurisdiction of the 49th Fighter Wing. ATC procedures and responsibilities are assumed by the Cherokee RADAR Control Facility (Cherokee Control) which is under the command of the 49FW. Normally at 2200 local time Cherokee Control contacts the military liaison at Albuquerque ARTCC to advise that WSMR is not active and the airspace is available for civilian use until 0600 the following morning. This information is passed on to all sectors within ZAB, all ARTCCs, ATCSCC, and AOCs.

As a result of the geographical location of this block of SUA, air traffic between LAX and DFW is affected and normally routed around WSMR. However, as indicated above, the increase in time and distance is not really significant in most cases. During periods of adverse weather, air traffic may be required to fly further south of WSMR, which necessitates coordination with the Mexican ATC facilities. According to specialists at ZAB (Albuquerque), this is a common occurrence. This alternate routing to the North could cause significant increases in time and distance.

There is a current Letter of Agreement in effect between ZAB, 49th Fighter Wing, 46th Test Group, and White Sands Missile Range, which outlines the procedures and the delegation of airspace related to the functions of these facilities. (Reference 4) Specialists at ZAB advise that they have become accustomed to working with Cherokee Control and the conditions associated with WSMR.

Additional analysis illustrates that elimination of restrictions over WSMR would produce a potential reduction in time and distance traveled of between 1% and 5% for flights from LAX to DFW.

The flight plans in Table 1 were produced using the GTE DUATS Flight Planning System with requested routes that would traverse the White Sands Missile Range. The preferred routes issued by the system were then compared for distance and time.

Operator/ Flight	**Dep./Des.**	**Route Filed**	**Distance (NMI)**	**Time At A Speed of 450kts**
SWA 123	LAX-DFW	KLAX LAX J74 J50 KOFFA J65 ABI DFW	1084.6 nmi	2 Hours 26 Minutes
UAL 345	LAX-DFW	KLAX LAX EWM J4 INK ABI JEN DFW	1118.3 nmi	2 Hours 30 Minutes
Direct Route	LAX-DFW	Great Circle- This route when plotted out does traverse the northern portion of the WSMR	1070.2 nmi	2 Hours 22 Minutes

Table 1 Flight plans from LAS to DFW through or around WSMR

The total savings in flight time and distance shown in this table are relatively small for a single flight. This result confirms the results of the study performed by Sverdrup,[28]

G.3 ATTRIBUTABLE TO FLEXIBLE SUA USE

Currently, there are **52** published Restricted areas in the continental United States and **9** Warning areas along coastal waters that are activated and deactivated by NOTAM only, and have no published regular times of operation. These blocks of airspace have varying horizontal and vertical dimensions extending into the En Route environment. These potentially could impact some flight trajectories throughout the NAS that were not aware of the closure prior to departure.

[28] Datta, Koushik and Craig Barrington, “Effects of Special Use Airspace on Economic Benefits of Direct Flights," Sverdup Corp., 1996.

Most of the 61 areas noted above are relatively small and, therefore, of limited impact. The large restricted areas (e.g., “the 28 complex” east of San Francisco, CA) is identified as in continuous use so that no access is allowed. If these areas are made available for civilian flights in the future, then closure would have to be monitored.

G.4 MAMS, SAMS, AND OASIS

The Military Airspace Management System (MAMS) and the Special use Airspace Management System (SAMS) maintained by the DoD are scheduling systems. As an example, a Military Operations Area (MOA) can be scheduled to be active on Monday through SAMS and MAMS. The cancellation of the planned exercise on Monday may never be distributed. Letters of agreement between the military and civilian organizations provide a manual means of monitoring SUA needs and availability.

The Operational & Supportability Implementation System (OASIS) is an FAA flight service station automation system which provides SUA status information. The OASIS program was not fully funded in FY 1999.

G.5 REGULATIONS

Federal Aviation Regulations Part 73-Special Use Airspace

SFAR53 Establishment of Warning Areas in the Airspace Overlying the Waters Between 3 and 12 Nautical Miles from the United States Coast

SFAR53.1 Applicability.

This rule establishes warning areas in the same location as non-regulatory warning areas previously designated over international waters. This special regulation does not affect the validity of any non-regulatory warning area which is designated over international waters beyond 12 nautical miles from the coast of the United States. This special regulation expires on January 15, 1996.

SFAR53.2 Definition.

Warning area. A warning area established under this special rule is airspace of defined dimensions, extending from 3 to 12 nautical miles from the coast of the United States, that contains activity which may be hazardous to nonparticipating aircraft. The purpose of such warning areas is to warn nonparticipating pilots of the potential danger. Part 91, Subpart B, is applicable within the airspace designated under this special rule.

Non-regulatory warning area. A non-regulatory warning area is airspace of defined dimensions designated over international waters that contains activity which may be hazardous to nonparticipating aircraft. The purpose of such warning areas is to warn nonparticipating pilots of the potential danger.

SFAR53.3 Participating aircraft.

Each person conducting an aircraft operation within a warning area designated under this special rule and operating with the approval of the using agency may deviate from the rules of Part 91, Subpart B, to the extent that the rules are not compatible with approved operations.

SFAR53.4 Nonparticipating aircraft.

Nonparticipating pilots, while not excluded from the warning areas established by this SFAR, are on notice that military activity, which may be hazardous to nonparticipating aircraft, is conducted in these areas.

Subpart A - General

73.1 Applicability.

The airspace that is described in Subpart B and Subpart C of this part is designated as special use airspace. These parts prescribe the requirements for the use of that airspace.

73.3 Special use airspace.

(a) Special use airspace consists of airspace of defined dimensions identified by an area on the surface of the earth wherein activities must be confined because of their nature, or wherein limitations are imposed upon aircraft operations that are not a part of those activities, or both.

(b) The vertical limits of special use airspace are measured by designated altitude floors and ceilings expressed as flight levels or as feet above mean sea level. Unless otherwise specified, the word "to" (an altitude or flight level) means "to and including" (that altitude or flight level).

(c) The horizontal limits of special use airspace are measured by boundaries described by geographic coordinates or other appropriate references that clearly define their perimeter.

(d) The period of time during which a designation of special use airspace is in effect is stated in the designation.

73.5 Bearings; radials; miles.

(a) All bearings and radials in this part are true from point of origin.

(b) Unless otherwise specified, all mileage in this part are stated as statute miles.

Subpart B - Restricted Areas

73.11 Applicability.

This subpart designates restricted areas and prescribes limitations on the operation of aircraft within them.

73.13 Restrictions.

No person may operate an aircraft within a restricted area between the designated altitudes and during the time of designation, unless he has the advance permission of

(a) The using agency described in § 73.15; or

(b) The controlling agency described in § 73.17.

73.15 Using agency.

(a) For the purposes of this subpart, the following are using agencies;

(1) The agency, organization, or military command whose activity within a restricted area necessitated the area being so designated.

(b) Upon the request of the FAA, the using agency shall execute a letter establishing procedures for joint use of a restricted area by the using agency and the controlling agency, under which the using agency would notify the controlling agency whenever the controlling agency may grant permission for transit through the restricted area in accordance with the terms of the letter.

(c) The using agency shall -

(1) Schedule activities within the restricted area;

(2) Authorize transit through, or flight within, the restricted area as feasible; and

(3) Contain within the restricted area all activities conducted therein in accordance with the purpose for which it was designated.

73.17 Controlling agency.

For the purposes of this part, the controlling agency is the FAA facility that may authorize transit through or flight within a restricted area in accordance with a joint-use letter issued under § 73.15.

73.19 Reports by using agency.

(a) Each using agency shall prepare a report on the use of each restricted area assigned thereto during any part of the preceding 12-month period ended September 30, and transmit it by the following January 31 of each year to the Manager, Air Traffic Division in the regional office of the Federal Aviation Administration having jurisdiction over the area in which the restricted area is located, with a copy to the Program Director for Air Traffic Operations, Federal Aviation Administration, Washington, DC 20591.

(b) In the report under this section the using agency shall:

(1) State the name and number of the restricted area as published in this part, and the period covered by the report.

(2) State the activities (including average daily number of operations if appropriate) conducted in the area, and any other pertinent information concerning current and future electronic monitoring devices.

(3) State the number of hours daily, the days of the week, and the number of weeks during the year that the area was used.

(4) For restricted areas having a joint-use designation, also state the number of hours daily, the days of the week, and the number of weeks during the year that the restricted area was released to the controlling agency for public use.

(5) State the mean sea level altitudes or flight levels (whichever is appropriate) used in aircraft operations and the maximum and average ordinate of surface firing (expressed in feet, mean sea level altitude) used on a daily, weekly, and yearly basis.

(6) Include a chart of the area (of optional scale and design) depicting, if used, aircraft operating areas, flight patterns, ordnance delivery areas, surface firing points, and target, fan, and impact areas. After once submitting an appropriate chart, subsequent annual charts are not required unless there is a change in the area, activity or altitude (or flight levels) used, which might alter the depiction of the activities originally reported. If no change is to be submitted, a statement indicating "no change" shall be included in the report.

(7) Include any other information not otherwise required under this part which is considered pertinent to activities carried on in the restricted area.

(c) If it is determined that the information submitted under paragraph (b) of this section is not sufficient to evaluate the nature and extent of the use of a restricted area, the FAA may request the using agency to submit supplementary reports. Within 60 days after receiving a request for additional information, the using agency shall submit such information as the Program Director for Air Traffic Operations considers appropriate. Supplementary reports must be sent to the FAA officials designated in paragraph (a) of this section.

Subpart C - Prohibited Areas

73.81 Applicability.

This subpart designates prohibited areas and prescribes limitations on the operation of aircraft therein.

73.83 Restrictions.

No person may operate an aircraft within a prohibited area unless authorization has been granted by the using agency.

73.85 Using agency.

For the purpose of this subpart, the using agency is the agency, organization or military command that established the requirements for the prohibited area.

Section 4 of the Aeronautical Information Manual - SPECIAL USE AIRSPACE

3-4-1. GENERAL

a. Special use airspace consists of that airspace wherein activities must be confined because of their nature, or wherein limitations are imposed upon aircraft operations that are not a part of those activities, or both. Except for Controlled Firing Areas, special use airspace areas are depicted on aeronautical charts.

b. Prohibited and Restricted Areas are regulatory special use airspace and are established in FAR Part Part 73 through the rulemaking process.

c. Warning Areas, Military Operations Areas (MOA), Alert Areas, National Security Areas (NSA) and Controlled Firing Areas (CFA) are non-regulatory special use airspace.

d. Special use airspace descriptions (except NSAs and CFAs) are contained in FAA Order 7400.8.

e. Special use airspace (except CFAs) are charted on IFR and Visual charts and include the hours of operation, altitudes, and the controlling agency.

3-4-2. PROHIBITED AREAS

Prohibited Areas contain airspace of defined dimensions identified by an area on the surface of the earth within which the flight of aircraft is prohibited. Such areas are established for security or other reasons associated with the national welfare. These areas are published in the Federal Register and are depicted on aeronautical charts.

3-4-3. RESTRICTED AREAS

a. Restricted Areas contain airspace identified by an area on the surface of the earth within which the flight of aircraft, while not wholly prohibited, is subject to restrictions. Activities within these areas must be confined because of their nature or limitations imposed upon aircraft operations that are not a part of those activities or both. Restricted areas denote the existence of unusual, often invisible, hazards to aircraft such as artillery firing, aerial gunnery, or guided missiles. Penetration of Restricted Areas without authorization from the using or controlling agency may be extremely hazardous to the aircraft and its occupants. Restricted Areas are published in the Federal Register and constitute FAR Part Part 73.

b. ATC facilities apply the following procedures when aircraft are operating on an IFR clearance (including those cleared by ATC to maintain VFR ON TOP) via a route which lies within joint-use restricted airspace.

1. If the restricted area is not active and has been released to the controlling agency (FAA), the ATC facility will allow the aircraft to operate in the restricted airspace without issuing specific clearance for it to do so.

2. If the restricted area is active and has not been released to the controlling agency (FAA), the ATC facility will issue a clearance which will ensure the aircraft avoids the restricted airspace unless it is on an approved altitude reservation mission or has obtained its own permission to operate in the airspace and so informs the controlling facility.

NOTE - The above apply only to joint-use restricted airspace and not to prohibited and non joint-use airspace. For the latter categories, the ATC facility will issue a clearance so the aircraft will avoid the restricted airspace unless it is on an approved altitude reservation mission or has obtained its own permission to operate in the airspace and so informs the controlling facility.

c. Restricted airspace is depicted on the Enroute Chart appropriate for use at the altitude or flight level being flown. For joint-use restricted areas, the name of the controlling agency is shown on these charts. For all prohibited areas and non joint-use restricted areas, unless otherwise requested by the using agency, the phrase "NO A/G" is shown.

3-4-4. WARNING AREAS

A Warning area is airspace of defined dimensions, extending from three nautical miles outward from the coast of the United States, that contains activity that may be hazardous to nonparticipating aircraft. The purpose of such warning areas is to warn nonparticipating pilots of the potential danger. A warning area may be located over domestic or international waters or both.

3-4-5. MILITARY OPERATIONS AREAS (MOA)

a. MOAs consist of airspace of defined vertical and lateral limits established for the purpose of separating certain military training activities from IFR traffic. Whenever a MOA is being used, nonparticipating IFR traffic may be cleared through a MOA if IFR separation can be provided by ATC. Otherwise, ATC will reroute or restrict nonparticipating IFR traffic.

b. Most training activities necessitate acrobatic or abrupt flight maneuvers. Military pilots conducting flight in Department of Defense aircraft within a designated and active MOA are exempted from the provisions of FAR Part 91.303(c) and (d) which prohibit acrobatic flight within Federal airways and Class B, Class C, Class D, and Class E surface areas.

c. Pilots operating under VFR should exercise extreme caution while flying within a MOA when military activity is being conducted. The activity status (active/inactive) of MOAs may change frequently. Therefore, pilots should contact any FSS within 100 miles of the area to obtain accurate real-time information concerning the MOA hours of operation. Prior to entering an active MOA, pilots should contact the controlling agency for traffic advisories.

d. MOAs are depicted on Sectional, VFR Terminal, Area and Low Altitude Enroute Charts.

3-4-6. ALERT AREAS

Alert Areas are depicted on aeronautical charts to inform nonparticipating pilots of areas that may contain a high volume of pilot training or an unusual type of aerial activity. Pilots should be particularly alert when flying in these areas. All activity within an Alert Area shall be conducted in accordance with FARs, without waiver, and pilots of participating aircraft as well as pilots transiting the area shall be equally responsible for collision avoidance.

3-4-7. CONTROLLED FIRING AREAS

CFAs contain activities which, if not conducted in a controlled environment, could be hazardous to nonparticipating aircraft. The distinguishing feature of the CFA, as compared to other special use airspace, is that its activities are suspended immediately when spotter aircraft, radar, or ground lookout positions indicate an aircraft might be approaching the area. There is no need to chart CFAs since they do not cause a nonparticipating aircraft to change its flight path.

3-4-8. NATIONAL SECURITY AREAS

National Security Areas consist of airspace of defined vertical and lateral dimensions established at locations where there is a requirement for increased security and safety of ground facilities. Pilots are requested to voluntarily avoid flying through the depicted NSA. When it is necessary to provide a greater level of security and safety, flight in NSAs may be temporarily prohibited by regulation under the provisions of FAR Part 99.7. Regulatory prohibitions will be issued by ATA-400 and disseminated via NOTAM. Inquiries about NSAs should be directed to the Airspace and Rules Division, ATA-400.

3-5-2. MILITARY TRAINING ROUTES

a. National security depends largely on the deterrent effect of our airborne military forces. To be proficient, the military services must train in a wide range of airborne tactics. One phase of this training involves "low level" combat tactics. The required maneuvers and high speeds are such that they may occasionally make the see and avoid aspect of VFR flight more difficult without increased vigilance in areas containing such operations. In an effort to ensure the greatest practical level of safety for all flight operations, the Military Training Routes (MTR) program was conceived.

b. The MTRs program is a joint venture by the FAA and the Department of Defense (DOD). MTR routes are mutually developed for use by the military for the purpose of conducting low altitude, high speed training. The routes above 1,500 feet AGL are developed to be flown, to the maximum extent possible, under IFR. The routes at 1,500 feet AGL and below are generally developed to be flown under VFR.

c. Generally, MTRs are established below 10,000 feet MSL for operations at speeds in excess of 250 knots. However, route segments may be defined at higher altitudes for purposes of route continuity. For example, route segments may be defined for descent, climbout, and mountainous terrain. There are IFR and VFR routes as follows:

1. IFR Military Training Routes - IR: Operations on these routes are conducted in accordance with IFRs regardless of weather conditions.

2. VFR Military Training Routes - VR: Operations on these routes are conducted in accordance with VFRs except, flight visibility shall be 5 miles or more; and flights shall not be conducted below a ceiling of less than 3,000 feet AGL.

d. Military training routes will be identified and charted as follows:

1. Route identification.

(a) MTRs with no segment above 1,500 feet AGL shall be identified by four number characters; for example, IR1206, VR1207.

(b) MTRs that include one or more segments above 1,500 feet AGL shall be identified by three number characters; for example, IR206, VR207.

(c) Alternate IR/VR routes or route segments are identified by using the basic/principal route designation followed by a letter suffix, for example, IR008A, VR1007B, etc.

2. Route charting.

(a) IFR Low Altitude Enroute Chart - This chart will depict all IR routes and all VR route that accommodate operations above 1,500 feet AGL.

(b) VFR Sectional Charts - These charts will depict military training activities such as IR, VR, MOA, restricted area, warning area, and alert area information.

(c) Area Planning (AP/1B) Chart (DOD Flight Information Publication - FLIP). This chart is published by the DOD primarily for military users and contains detailed information on both IR and VR routes.

f. Nonparticipating aircraft are not prohibited from flying within an MTR; however, extreme vigilance should be exercised when conducting flight through or near these routes. Pilots should contact FSSs within 100 NM of a particular MTR to obtain current information or route usage in their vicinity. Information available includes times of scheduled activity, altitudes in use on each route segment, and actual route width. Route width varies for each MTR and can extend several miles on either side of the charted MTR centerline. Route width information for IR and VR MTRs is also available in the FLIP AP/1B along with additional MTR (SR/AR) information. When requesting MTR information, pilots should give the FSS their position, route of flight, and destination in order to reduce frequency congestion and permit the FSS specialist to identify the MTR routes that could be a factor.